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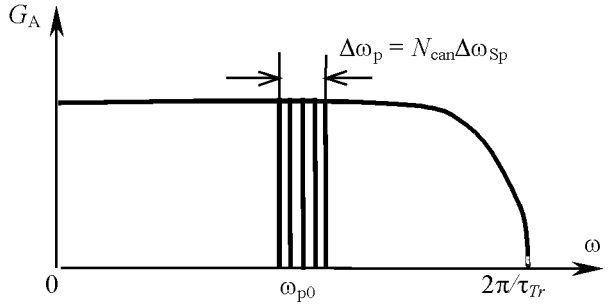
Spacetime & Substance

International Physical Journal



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THE ROLE OF CONSERVATION LAWS IN EVOLUTIONARY PROCESSES

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The paper concerns some specific features of the conservation laws that explain the evolutionary process in the material systems and a mechanism of formation of physical fields. It is known that in the material systems the conservation laws for energy, linear momentum, angular momentum, and mass are valid. These conservation laws establish a balance between a change of a physical quantity and a relevant action to the system. Such conservation laws may be referred to as balance conservation laws. To the physical structures that format the physical fields there correspond the conservation laws as preserving physical quantities. In the work it was shown that a transition from the balance conservation laws for material systems to the conservation laws for physical fields corresponds to an origin of the physical structures and a formation of the physical fields. In material systems it reveals in the form of origin of new formations (pulsations, waves vortices, creation of particles) that are observable and measurable. We show that the noncommutativity of the balance conservation laws is the basis of these processes.
Such results have been obtained by means of a mathematical tool utilizing the exterior differential forms.
In the work a role of the conservation laws in formation of the pseudometric and metric spaces is shown.

1. Introduction

At present there are many problems associated with the conservation laws. An approach to the conservation laws, their mathematical expression and physical treatment turn out to be different in different branches of science. A concept "the conservation law" in different branches of science carry different sense. In physics the conservation laws reveal themselves as conservative quantities (such conservation laws may be called exact ones); in mechanics of continuous media these conservation laws establish a balance between a change of physical quantities (energy, linear momentum, angular momentum, and mass) and relevant external forcing (such conservation laws may be called the balance conservation laws); in thermodynamics the conservation laws prove to be relevant to the principles of thermodynamics. And what have they in common?

The exact conservation laws relate to **physical fields**. {Physical fields (electromagnetic, gravitational, nuclear and etc) [1] are special forms of the matter which are carriers of interactions}. The balance conservation laws are those for **material systems**. {A material system is a variety of elements which have internal structure and interact to one another. Examples of elements that constitute the material system are electrons, protons, neutrons, atoms, fluid particles, cosmic objects and others. As examples of material systems it may be thermodynamic, gas dynamical, cosmic systems, systems of elementary particles (pointed above) and others. The physical vacuum in its properties may be regarded as an analogue of the material system that generates some physical fields}. As it will be shown in Appendix, the principles of thermodynamics are not special balance conservation laws. They combine the balance conservation laws for energy and linear momentum, and it enables one to understand a nature of their interactions.

In the present work we show that the exact conservation laws follow from the balance conservation laws. And **an interaction of the balance conservation laws that appear to be noncommutative** plays a crucial role. {The principles of thermodynamics may be regarded as an example of accounting for this interaction in the thermodynamic systems}. A transition from the balance conservation laws to the exact ones is accompanied by origin of the physical structures and it forms the basis of the evolutionary processes [2-7]. It is evident that material systems generate the physical structures, and such structures format the physical fields.

In section 1 some properties of the exterior forms utilized in the work are presented. In section 2 it is shown that the closed forms may correspond to the exact conservation laws. {For the sake of clearness in sections 2-8 we introduce a double notation. By simple lettering and by italic one we respectively designate a name, which has a physical sense, and that, which ex-

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plains the mathematical sense}. In the next sections we demonstrate a noncommutativity of the balance conservation laws, establish a relation between the balance conservation laws and exact those, and disclose a mechanism of origin of the physical structures that produce the physical fields.

In Appendix 1 we show that the invariant and metric properties of the closed exterior differential forms constitute the basis of existing field theories. In Appendix 2 we give an analysis of the principles of thermodynamics that disclose an interaction of the balance conservation laws for energy and for linear momentum. In Appendix 3 it was shown an influence of the noncommutativity of the balance conservation laws on a development of instability. In Appendix 4 equations of the electromagnetic field were analyzed. In Appendix 5 we present a table of interactions. In Appendix 6 a role of the conservation laws in formation of the pseudometric and metric spaces is shown, and an analysis of the Riemann space and the Einstein equation is presented. In Appendix 7 functional properties of solutions to the differential equations, that are essential for the field theory, are analyzed. These properties reflect those of the conservation laws.

2. Some properties of exterior differential forms

An exterior differential form of degree p (p-form) may be presented as [8-14]

$$\theta^p = A_{\alpha_1 \dots \alpha_p} dx^{\alpha_1} dx^{\alpha_2} \dots dx^{\alpha_p}, \quad 0 \le p \le n \tag{1}$$

where the basic dx^α, $dx^\alpha dx^\beta$, $dx^\alpha dx^\beta dx^\gamma$, ... obey the condition

$$dx^\alpha dx^\alpha = 0$$

$$dx^\alpha dx^\beta = -dx^\beta dx^\alpha \quad \alpha \neq \beta. \tag{2}$$

A differential (exterior) of the form θ^p is expressed by the formula

$$d\theta^p = dA_{\alpha_1 \dots \alpha_p} dx^{\alpha_1} dx^{\alpha_2} \dots dx^{\alpha_p} \tag{3}$$

and it proves to be the differential form of degree $(p+1)$.

We will point out some properties of the closed forms that correspond to the exact conservation laws.

1) A closure condition of the p-form θ^p (form of degree p) is written as

$$d\theta^p = 0 \tag{4}$$

(it is obvious that the closed form is a conservative quantity).

2) If a form is closed only on some structure, i.e. on pseudostructure, then the closure condition may be written in the form

$$d_\pi \theta^p = 0, \tag{5}$$

where the pseudostructure π obeys the condition

$$d_\pi {}^*\theta^p = 0, \tag{6}$$

here ${}^*\theta^p$ is the dual form. (One can see that a form closed on pseudostructure is a preserving object). {To the exterior differental form on the differentiable manifold there corresponds the skew-symmetric tensor. To the dual form that describes the pseudostructure there corresponds the pseudotensor dual to the skew-symmetric tensor. The pseudostructures format cohomologies (cohomologies by De Rham, singular cohomologies [8]), sections of the cotangent bundles and so on. They correspond to eikonals which are on one hand the level surfaces and on the other the cut surfaces}.

3) A form is called exact one if it is equal to total differential:

$$\theta^p = d\theta^{p-1}. \tag{7}$$

The exact forms are closed identically: $d\theta^p = d\, d\theta^{p-1} = 0$

4) Any closed form is a differential. An exact form is a total differential. A closed inexact form is an interior one on the pseudostructure differential.

$$\theta^p = d_\pi \theta^{p-1}. \tag{8}$$

5) From Eqs. (7) and (8) it follows that there exist a connection between forms of sequent degrees. There is also a similar integral relation

$$\int_{c^{p+1}} d\theta^p = \int_{\partial c^{p+1}} \theta^p.$$

The theorems by Stokes and Gauss are special cases of this relation.

From the definition of the form it follows that elements of differential of the form are equal to components of their commutator. Thus, if the form of first degree is expressed as $\theta = a_\mu d\xi^\mu$, then $d\theta = K_{\alpha\beta} d\xi^\alpha d\xi^\beta$, where components of the form commutator are $K_{\alpha\beta} = a_{\beta;\alpha} - a_{\alpha;\beta}$. Here $a_{\beta;\alpha}$, $a_{\alpha;\beta}$ are the covariant derivatives. In the case of differentiable manifold the covariant derivatives coinside with ordinary ones and the commutator components can be written as

$$K_{\alpha\beta} = \left(\frac{\partial a_\beta}{\partial \xi^\alpha} - \frac{\partial a_\alpha}{\partial \xi^\beta} \right). \tag{9}$$

If a form is defined on the nondifferentiablle manifold, then an additional term will appear in the commutator, this term is a commutator of the metric form of manifold.

3. Conservation laws for physical fields. (A closure condition of exterior forms)

As it is seen from the closure conditions (4), (5), a closed form is a conservative quantity, and hence it may correspond to the exact conservation law. And the closed inexact form is a conservative object, namely, it is a conservative quantity only on some pseudostructure π. The closure conditions for the exterior form ($d_\pi\, \theta^p = 0$) and the dual form ($d_\pi\, {}^*\theta^p = 0$) are mathematical expression of the exact conservation law.

The exact conservation laws correspond to physical structures that format physical fields. Preserving objects, e.g. conservative quantities (closed exterior forms), on the pseudostructures (dual forms) are the physical structures that format physical fields:

$$\begin{cases} d_\pi \theta^p = 0 \\ d_\pi {}^*\theta^p = 0 \end{cases} \mapsto \begin{cases} \theta^p \\ {}^*\theta^p \end{cases} \text{— physical structures} \mapsto$$

$$\mapsto \text{physical fields}$$

Equations for the physical structures ($d_\pi\, \theta^p = 0$, $d_\pi\, {}^*\theta^p = 0$) turn out to coincide with a mathematical expression of the exact conservation law. It is seen that the exact conservation law is that for physical fields.

As any closed form is a differential (either total if the form is exact one: $\theta^p = d\theta^{p-1}$, or interior on the pseudostructure: $\theta^p = d_\pi\, \theta^{p-1}$ if the form is inexact) of the form of lower degree, then the form of lower degree may correspond to a potential. And the form degree indicates a type of potential. The potential is a scalar if $l = 0$ ($l = p - 1$), it is a vector if $l = 1$, and it is a tensor if $l = 2, 3$. The closed inexact forms of zero, first and second degrees relate respectively to the pseudoscalar, pseudovector and pseudotensor (vortex) fields. {As it was pointed before, the closed form is a conservative quantity. On the other hand, as it is a differential of some form, which in this case plays a role of the potential, the closed form reveals as a potential force. That is, the closed form is dual object. This duality of the closed forms discloses properties of the physical fields decribed as the carriers of interactions. Below it will be shown, with respect to what the closed form reveals as a potential force.}

Thus, an application of the closed exterior differential forms enable one to see a relation between the conservation laws and the physical structures that produce physical fields. It may be shown that invariant and metric properties of the closed exterior differential forms that correspond to the exact conservation laws constitute the basis of the existing theories which describe physical fields. We are able to verify that all existing theories are complemented by additional conditions of invariance or covariance which are the closure conditions for exterior or dual forms. (In more details this subject is described in Appendix 1).

The existing field theories that are based on the exact conservation laws allow to describe physical fields, find possible physical structures, and understand a variety of physical fields. However, such invariant theories cannot give an answer to the question concerning a mechanism of the genesis of physical structures. Only a theory that does not base on the closure conditions for forms can give an answer. These conditions have to be achieved by themselves spontaneously. A realization of these conditions implies a formation of the closed form, and this corresponds to the conservation law and gives an indication of a production of physical structure. It is evident that only the evolutionary theory can answer the question about a mechanism of generation of the physical structures. Such a theory is one based on the balance conservation laws for the material systems. (It also bases on the properties of exterior forms, however, in this case the exterior form are defined on the nondifferentiable manifold, and therefore they are nonclosed. These forms are nonintegrable ones. Topological properties of commutators for such forms enable one to understand a role of the balance conservation laws in evolution processes and in formation of physical fields.

4. Noncommutativity of the balance conservation laws for material systems. (Nonidentity of the evolutionary relation obtained from the balance conservation laws)

The conservation laws for the material system (continuous medium) express the following [18]: a change of any physical quantity in some volume for a given time interval is balanced out by the flux of this quantity across the boundary of the volume and by the source actions. Under transition to the differntial expression the fluxes are substituted by divergences. And the differential or integral equation is supplemented with a dependence of the physical quantities on the state function of the material system. Below a relation (in the differential forms) for the state function will be obtained. Just this relation disclose a specifics of the evolutionary processes. It should be underlined once more that the conservation laws for the material medium are balance ones.

The balance conservation laws (for energy, linear momentum, angular momentum, and mass) establish a balance between a change of physical quantities and an action on the system. And every balance conservation law depends on relevant actions (so the conservation law for energy depends on energetic actions, the conservation law for linear momentum does on force ones, etc). In real processes such actions have a different nature. Therefore the balance conservation laws prove to

be noncommutative. {What is the "noncommutativity" of the balance conservation laws? Suppose, that first the energetic and then the force perturbations act on a local domain of the material system (element and its neighborhood). And let at the initial moment the local domain be in some state **A**. According to the balance conservation law for energy, under an influence of the energetic perturbation the local domain develops from the state **A** into any state **B**. Then according to the balance conservation law for momentum under an influence of the force perturbation it develops from the state **B** into any state **C**. Suppose now that the sequence of the actions changes, namely, first the force perturbation and then the energetic one act, and the system develops first into any state $\mathbf{B}^*$ and then does into the state $\mathbf{C}^*$. If the state $\mathbf{C}^*$ coincides with the state **C**, that is, the result does not depend on a sequence of perturbation of different type (and on a sequence of performing the relevant balance conservation laws), then it means that the balance conservation laws commutate. If the state $\mathbf{C}^*$ does not coincide with the state **C**, then it means that the balance conservation laws prove to be noncommutative}. This is just of decisive importance for evolutionary processes and a mechanism of origin of the physical structures. Because of noncommutativity of the balance conservation laws, an external forcing that experience the material system cannot directly convert into physical quantities (energy, linear momentum, angular momentum, mass) of the system, but they convert into some quantity that acts as internal force and is a cause of the evolutionary processes.

To understand how the balance conservation laws interact to one another it is necessary to study a conjunction (self-consistence) of equations governing these laws.

The balance conservation laws may be described by means of differential equations [15-18]. If the material system is not dynamical one (as in the case of thermodynamic system), then the equations of the balance conservation laws may be written in terms of increments of physical quantities and governing variables.

Equations are conjugate ones if they may be contracted into identical relations for differential, i.e. for a closed form. Let analyze the equations that describe the balance conservation laws for energy and linear momentum.

We introduce two frames of reference: the first is inertial one (this system is not connected with the material system), and the second is accompanying one (this system is connected with a manifold created by trajectories of elements of the material system). The energy equation in the inertial frame of reference may be reduced to the form:

$$\frac{D\psi}{Dt} = A, \tag{10}$$

where D/Dt is the total derivative with respect to time, ψ is the functional of the state that specifies the material system, A is a quantity, which depends on specific features of the system and on external energy actions on the system. The action functional, entropy, wave function may be regarded as examples of the functional ψ. Thus, the equation for energy represented in terms of the action functional S has a similar form: $DS/Dt = L$, where $\psi = S$, $A = L$ is the Lagrange function. In mechanics of continuous media the equation for energy of ideal gases may be presented in the form [16]: $Ds/Dt = 0$, where s is entropy. In this case $\psi = s$, $A = 0$. It is worth note that the examples presented show the mutual relation between the action functional and entropy.

In the accompanying frame of reference a total derivative with respect to time transforms into that along the trajectory. The equation (10) turns out to be written in the form

$$\frac{\partial\psi}{\partial\xi^1} = A_1, \tag{11}$$

here ξ^1 is a coordinate along the trajectory. In a similar manner, in the accompanying frame of reference the equation for linear momentum appears to be reduced to the equation of the form

$$\frac{\partial\psi}{\partial\xi^\nu} = A_\nu, \quad \nu = 2, \ldots, \tag{12}$$

where ξ^ν are coordinates in the direction being normal to the trajectory, A_ν are the quantities that depend on specific features of the system and external force actions.

The Eqs. (11), (12) may be convoluted into the relation

$$d\psi = A_\mu\, d\xi^\mu, \quad (\mu = 1, \nu), \tag{13}$$

where $d\psi$ is the differential expression $d\psi = (\partial\psi/\partial\xi^\mu)d\xi^\mu$.

The relation (13) may be written in the form:

$$d\psi = \omega, \tag{14}$$

here $\omega = A_\mu\, d\xi^\mu$ is the differential form of the first degree.

As the balance conservation laws are evolutionary ones then the relation obtained is also evolutionary law. The proper evolution relation corresponds to every material system (see Appendices (2)-(4)}.

The relation (14) has been obtained from the balance conservation laws for energy and linear momentum. In this context the form ω is that of the first degree. If the equations of the balance conservation laws for angular momentum be added to the equations for energy and linear momentum, then in the evolutionary relation this form will be that of the second degree. And in a combination with the equation of the balance conservation law for mass this form will be a form of

degree 3. Thus, in the general case the evolutionary relation may be written in the form

$$d\psi = \omega^p ,$$

where the degree of the form p takes the values $p = 0, 1, 2, 3$.. (The evolutionary relation for $p = 0$ is similar to that in the differential forms, and it has been obtained from interaction of energy and time or momentum and coordinate.)

In the left-hand side of the evolutionary equation there is the functional expression $d\psi$, which specifies a state of the material system, and in the right-hand side there is the form ω^p which coefficients depend on external actions. The meaning of the evolutionary relation lies in a fact that it discloses a specific feature of dependence of the material system state on external actions. As it will be shown below, the evorutionary relation has a specific feature (it may be nonidentic one) which enables one to determine a mechanism of transition of the material system from nonequilibrum state to the equilibrum or locally equilibrum one, and this has a decisive importance for the evolutionary process. {It should be pointed out the following. If to a state of the material system there correspond a differential of any function, then this indicates that a state of the material system is the equilibrum or locally equilibrum one. And if the differential is absent, then this means that the system is in the nonequilibrum state. As it will be shown below, owing to this specific feature the evolutionary relation enables one to detect a presence or absence of the differential and as the result to classify a state of the system}.

At this point we show that for real processes **the evolutionary relation appears to be nonidentical one** . A relation may be identical one if it relates any measurable metric or invariant objects, i.e. the objects which may be compared. {A concept "nonidentic relation" may be seemed as contradictive one. However, this concept carries an in-depth meaning. The identic relation establishes an exact correspondence between quantities entering into that. The nonidentic relation can establish an exact correspondence between quantities entering into that only under some supplementary conditions. If these supplementary conditions do not satisfied, this relation has a physical meaning as well. If this relation is evolutionary one, then it proves to be a selfvariating relation, that is, a variation of one object of the relation forces a change of the other object, and in turn a change of the second object leads to a change of the first one and so on. As one object is nonmeasurable object, than the other object cannot be compared with the first one, and hense a process of selfvariation cannot be terminated without additional conditions. Additional conditions can be realized by themselves under a selfvariation of the nonidentic relation owing to any degrees of freedom. Just the nonidentic relations, which the evolutionary relations belong to, can describe a self-organization of the material systems. The principle of self-organization will be clarified later}.

Let as examine the relation (14). For real processes the form ω that stands in the evolutionary relation (14) and depends on the external actions appears to be nonclosed and hence cannot be an invariant object. For the form to be closed it needs the differential of the form or its commutator be zero (elements of a differential of the form are equal to components of its commutator). Let us consider a commutator of the form $\omega = A_\mu d\xi^\mu$. Components of the commutator may be written as follows:

$$K_{\alpha\beta} = \left(\frac{\partial A_\beta}{\partial \xi^\alpha} - \frac{\partial A_\alpha}{\partial \xi^\beta} \right), \tag{15}$$

(here a term that is connected with a nondifferentiability of the manifold was not taken into account as yet). Coefficients of the form ω have been obtained either from the balance conservation law for energy or from that for linear momentum. It means that in the first case the coefficients depend on the energetic action and in the second case they depend on the force action. In actual processes energetic and force actions have a different nature and appear to be nonconsistent. The commutator of the form ω constructed from derivatives of such coefficients is nonzero. This means that a differential of the form ω is nonzero as well. Thus, the form proves to be nonclosed and isn't an invariant object. Therefore, in the evolutionary relation there in noninvariant term. Such a relation cannot be identical one. Hence, without a knowledge of a particular expression for the form , one can argue that for an actual processes the evolutionary relation proves to be nonidentical because of nonconsistency of the external action. To emphasize this fact, it is reasonable to write down the relation (14) in the form

$$d\psi \cong \omega , \tag{16}$$

(it was introduced the sign $\cong$ instead of the equality sign $=$). In a similar manner one may prove the nonidentity of the general evolutionary relation and to write it in the form:

$$d\psi \cong \omega^p . \tag{17}$$

A nonidentity of the evolutionary relation means that equations of the balance conservation laws turn out to be nonconjugate (thus, if from the energy equation to obtain a derivative of ψ in the direction along the trajectory and from the momentum equation to find a derivative of ψ in the direction normal to the trajectory and next to calculate their mixed derivatives, then from the condition that the commutator of the form ω is nonzero it follows that mixed derivatives prove to be noncommutative). It points that these balance conservation laws don't commutate.

5. Nonequilibrum property of material system. Selfvariation of the state of material system. Topologic properties of commutator for nonintegrable form

What is follow from noncommutativity of the balance conservation laws? Let us analyze the evolutionary relation (14). If the balance conservation laws for energy and momentum be commutative, then the relation (14) turns out to be identic, and the differential $d\psi$ can be obtained from that. It may be regarded that ψ is a function of the state. And an existence of the function of state means that the state is locally balanced one. This means that external actions directly transform into physical measurable quantities of the system, namely, energy and momentum of elements of the material system. But because of the evolutionary relation is not identical, one cannot obtain the differential $d\psi$ from that relation, and this means that there is no the function of state. The state of system is nonequilibrum one. Because of the noncommutativity of the balance conservation laws, the external forces cannot directly transform into measurable quantities of the system, and they transform into any nonmeasurable quantity. This nonmeasurable quantity, which is described by the commutator of the form ω, acts as internal force. This means that because of the noncommutativity of the balance conservation laws the state of material system proves to be nonequilibrum one and there is an internal force described by the commutator of the nonintegrable form ω. In the general case this nonmeasurable quantity is described by the commutator of the nonintegrable form ω^p. The nonequilibrum is a moving force of the evolutionary process. A further analysis of the evolutionary relation and the commutator of the form ω^p allows to understand a mechanism of the evolutionary process.

A nonidentical relation, if it is a evolutionary relation, appears to be selfvariating: a change of any object of the relation forces a change of other object and in turn a change of the second object leads to a change of the first one and so on. As one of objects of the nonidentical relation is nonmeasurable object, then the other object cannot be exactly compared with the first object. This property of the nonidentical evolutionary relation makes it possible to describe a selfvariation of the nonequilibrum state of the material system. In this case topologic properties of the commutator of nonintegrable form (this form is defined on the nonintegrable manifold) play a deciding role.

If manifold, on which the exterior form is defined, is nondifferentiable one, then an additional term that contains a commutator of the metric form of manifold (this commutator specifies a deformation of the manifold) will enter into a commutator of the exterior form. The form ω^p, that stands in the evolutionary relation, is defined on the accompanying manifold, which for actual processes turns out to be nondifferentiable one as it is formatted contemporaneously with a change of the state of material system and depends on the physical processes. Hence, a term containing the characteristics of the manifold will enter into a commutator of the form ω^p in addition to a term, which is connected with derivatives of coefficients of the form. An interaction between these terms of different nature just describes a mutual change of the state of material system.

Let us examine this with an example of commutator of the form $\omega = A_\mu\, d\xi^\mu$ that enters into the evolutionary relation (14). We assume that at the beginning an associated manifold was differentiable. In this case a commutator of the form ω can be written in the form (15). If at the next point in time any action effects on the material system, then this commutator turns out to be nonzero. A state of the material system becomes nonequilibrum and it will appear an internal force whose action will lead to a deformation of the accompanying manifold. Then the accompanying manifold fails to be differentiable. In a commutator of the form ω it will appear an additional term, that specifies a deformation of the manifold and is a commutator of the metric form of manifold. If it is possible to define the coefficients of connectivity $\Gamma^\sigma_{\alpha\beta}$ (for nondifferentiable manifold they are asymmetric ones), then a commutator of the form may be written as

$$K_{\alpha\beta} = \left(\frac{\partial A_\beta}{\partial \xi^\alpha} - \frac{\partial A_\alpha}{\partial \xi^\beta}\right) + (\Gamma^\sigma_{\beta\alpha} - \Gamma^\sigma_{\alpha\beta})\, A_\sigma, \quad (18)$$

where $(\Gamma^\sigma_{\beta\alpha} - \Gamma^\sigma_{\alpha\beta})$ is a commutator of the metric form (which specifies a torsion of manifold). An emergence of the second term can only change a commutator and cannot make it zero (because terms of the commutator have different nature). In the material system the internal force will continue to act even without external actions. The further deformation (torsion) will go on. This leads to a change of commutator of the metric form, produces a change of the exterior form and its commutator and so on. A process of selfvariation of the commutator that governs by nonidentic evolutionary relation specifies a change of the external force and selfvariation of nonequilibrum state of the material system. At this point it should be emphasized that such selfvariation of the state of material system proceeds under an action of internal (rather then external) forces and may go on even without action of external forces. And a state of material system remains nonequilibrum, and in actual physical process an internal force could give rise to development of instability in the material system. {For example, this was pointed out in works by Prigogine [19]. "The excess entropy" in his works is analogous to a commutator of nonintegrable form for thermodynamic system. "A production of excess entropy" leads to development of instability}. An

internal force cannot continuously become equal to zero. The material system cannot continuously transform into an equilibrum (without internal forces) state. However, in the material system an equilibrum state may be locally realized if internal forces transform into potential ones. As an analyses of the evolutionary equation shows, it is possible under additional conditions and it corresponds to emergence of the physical structure.

6. A mechanism of origin of the physical structure. (Degenerate transformation)

For actual processes a differential of the form ω^p that enters into the evolutionary equation (as well as the commutator) is nonzero:

$$d\,\omega^p \neq 0, \tag{19}$$

i.e. the form ω^p is nonclosed. To the physical structure one has to assign a closed form on pseudostructure, that is to say, that to the physical structure there corresponds some differential $d_\pi \psi$. Such a differential may be obtained from the evolutionary relation only if the form ω^p is closed inexact one, in other words, if the form is subjected to the conditions

$$\begin{cases} d_\pi \omega^p = 0 \\ d_\pi \, {}^*\omega^p = 0 \end{cases}, \tag{20}$$

(in this case the form appears to be an interior differential of any form, namely $\omega^p = d_\pi \vartheta$. The evolutionary relation becomes identical on the pseudostructure π, and a differential $d_\pi \psi = d_\pi \vartheta$, that corresponds to the physical structure, can be determined from that relation).

A transition from the condition (19) to the condition (20) that corresponds to origin of the physical structure (and a transformation of internal forces into potential ones) is possible only as **the degenerate transform**, i.e. it is a transition which does not preserve a differential. {At this point it should be underlined that in this case the degenerate transform is realized as a transition from the accompanying frame of reference to the inertial one}. Some additional condition has to correspond to the degenerate transform. (A vanishing of such functional expressions as Jacobians, determinants, the Poisson brackets, and others may be regarded as examples of such conditions). Because the evolutionary relation describes the material systems and coefficients of the form depend on properties of the material system, then it is evident that a condition of the degenerate transform has to be caused by properties of the material system. As an example, the system may have any degrees of freedom. Namely, under realization of any degree of freedom it may take place a redistribution between physical quantities (for example, between energy and linear momentum) in such a way that they become measurable simultaneously . Such degrees of freedom may be translational ones, internal degrees of freedom of elements of the system and so on.

Thus, the physical structure can arise, if, firstly, the material system undergoes nonconsistent external actions and *a commutator of the form ω^p is nonzero.* And, secondly, if the material system has degrees of freedom, i.e. *there are conjugation conditions for the exterior form ω^p*. However, even if these conditions are satisfied, the physical structure appears only in the case, when degrees of freedom of the system are realized (in physical process), namely, *the conditions of conjugation are satisfied.* It may take place under self-variation of the state of material system. And it may be realized only spontaneously because it is caused by internal (rather then external) reasons (degrees of freedom are characteristics of the material system and not of external actions).

A creation of the physical structure is a transition of a quantity that acts as internal force into a measurable quantity that acts in the direction normal to the pseudostructure as potential force . {Above it was poined out the duality of the closed form (as conservative quantity and as potential force). This duality has a physical meaning. The closed form as conservative quantity relates to the physical field. The object, which is conservative quantity on the pseudostructure, is an element of physical field. And the closed form reveals as potential force with respect to the material system. The potential force is an action of the formation originated (see below) on elements of the material system. The potential forces are described, for example, by jumps of derivatives in the direction normal to the characteristics, to the potential surfaces, and so on.}

The physical structure and some measurable quantity that acts as potential force reveal as a new measurable and observable formation that spontaneously arises in the material system. {Fluctuations, pulsations, waves, vortices, massless particles are examples of such formations}. In the physical process this formation spontaneously extracts from the local domain of material system and so it allows the local domain of material system to get rid of internal force and come into locally balanced state. A formation, that has been created in some local domain of the material system and liberated from that, begins to act on the neighboring local domain as a potential force (this forcing was created by system in itself, and therefore this is potential forcing (rather then arbitrary one). The neighboring domain of material system works over this action, which appears to be external for it. If in the process the conditions of conjugation turn out to be satisfied again, then the neighboring domain create a formation of its own. In such a way the formation can move relative to material system. A velocity of moving relative to material system is not a parameter of the system,

but this is some quantity that is realized at every time as the conjugation condition. If the material system is homogeneous one, then a velocity will have the same values (but this is not a constant because it anew arise at every point of time of the evolutionary process). The speed of sound, the speed of electromagnetic waves, the speed of light are formatted in such a way. It is evident, that a velocity of moving relative to material system is defined by internal properties of the system. (As example, the speed of sound $a : a^2 = (dp/d\rho)_s$, where the pressure p and density ρ are characteristics of the material system and the subscript s means a constancy of entropy).

7. Characteristics of a formation originated: intensity, spin, absolute and relative speeds of propagation of the formation. (Characteristics of exterior and dual forms, value of commutator of the nonintegrable form, properties of the material system)

As a formation originated is a result of transition of nonmeasurable quantity, which is described by the commutator (and acts like internal force), into measurable quantity (potential force), then it is evident that an intensity of the formation originated is defined by a quantity, which was stored by the commutator of the nonintegrable form at the moment of its appearing. And the first term of the commutator that formatted by mixed derivatives of the form coefficients governs an intensity of the formation, whereas the second term that specifies a deformation of the accompanying manifold (bending, torsion, curvature) is fixed as any internal characteristics of the formation originated. Spin is an example of such a characteristics, and a value of spin depends on degree of the form. An integrating direction, i.e. pseudostructure that is defined by the dual form, determines an absolute speed of propagation of the formation originated (it is a speed in the inertial frame of reference). The speed of propagation relative to the material system (a speed in the accompanying frame of reference), as examples of that are speed of sound, speed of light, speed of electromagnetic waves and so on, is defined by the conjugation conditions, i.e. by degrees of freedom of the material system.

In such a way the following correspondence is established:

1) an intensity of the formation (potential force) is *a value of the first term in the commutator of nonintegrable form* at the instance of formation creation;

2) spin is *the second term in the commutator that is connected with the metric commutator*;

3) a preserving quantity (a charge) is *the exterior form that has been realized*;

4) an absolute speed of propagation of the formation arisen (a speed in the inertial frame of reference) is the integrating direction–pseudostructure–*dual form*;

5) a speed of propagation relative to the material system (the speed of sound, the speed of light, the speed of electromagnetic wave) is a speed in the accompanying frame of reference–conjugation conditions–*additional conditions connected with properties of the material system.*

8. A formation of pseudometric and metric spaces. (An integration of the nonidentical evolutionary relation)

An analyses of integrability of the nonidentical evolutionary relation explains a process of formation of pseudostructures and thereby make more evident a mechanism of formation of pseudometric and metric space.

As it is known, the closed form is a differential (exterior or interior) of the form of one less degree. This connection enables one to carry out an integration of the closed form and proceed to the form of one less degree. Such transitions are possible only in identical relations. It may be shown that an integration and transitions with lowering the form degree are allowed in nonidentical relations (nonintegrable forms) as well but only in the case of degenerate transforms. Under a degenerate transform on the pseudostructure it may be obtained the identical relation that can be integrated and it enables one to get a relation with the forms of one less degree. The relation obtained turns out to be nonidentical as well. By integration (under realization of relevant degenerate transform) the nonidentical evolutionary relation with forms of degree p, one may successively obtain nonidentical relations with forms of degree k, where k takes values from p to 0. At each transition the closed forms on the pseudostructure of sequent degrees $k = p, k = p - 1, ..., k = 0$ are formatted, and this indicates a creation of the physical structures of relevant type. A transition to the exact form of zero degree corresponds to a creation of some element of the material system (massive particle with internal structure). {So called "spontaneous violation of the symmetry" is an example of such a transition}.

To a creation of the physical structures we put into correspondence a formation of the pseudostructures with a dimension which depends on the space dimension. It may be shown that under a generation of closed forms of sequent degrees $k = p, k = p - 1, ..., k = 0$ the pseudostructures of the dimensions $(n + 1 - k)$: $1, ..., n + 1$ are obtained (here n is a dimension of the initial inertial space). {When deriving the evolutionary relation two frames of reference were used. The first

system is inertial one which is connected with the space where the material system situates and is not directly connected with the material system. This is an inertial space, it is the metric space. The second frame of reference is proper one, it is connected with accompanying manifold which is not metric manifold}. When proceeding to the exact closed form of zero degree the metric structure of the dimension $n+1$ is obtained. As a result we get that under influence of nonconjugate external forcing (and if there are degrees of freedom) the material system can transform the initial inertial space of the dimension n into a space of the dimension $n+1$. {In the initial space of degree 0 it may be formatted a space of the dimension 1 (such a space may be a time). And in space of the dimension 1 it may be formatted a space of the dimension 2 (time and space coordinate) and so on. Every material system has their proper time. In particular, this approach explains how the proper time is formatted). In the initial space of the dimension 3 it may be formatted a space of the dimension 4 (time and three space coordinates). Such a space can be convoluted and a new dimension may happen to be nonrealizable. Thus, the cycle ends and a new cycle may begin (this corresponds to that one system may be embedded into the other one). A mechanism of formation of the pseudostructures and the metric structures can explain, in particular, how the internal construction of elements of the material system is formatted}. So it can be seen that the inertial spaces are not absolute spaces where actions are developed, but they are spaces generated by the material systems. A mechanism of formation of the pseudostructures is at the basis of creation of the pseudometric spaces and of their transition into the metric spaces. (In Appendix 6 a formation of pseudoriemann and Riemann's spaces are considered, and conditions of a derivation of the Einstein equation are analyzed).

It may be shown that equations of the characteristic surfaces, potential surfaces (simple or double layer), residue equation and others obtained from the equations of the mathematical physics are the equations of the pseudostructures. As the equations for pseudostructure there serve the eikonal equation (the pseudostructure is the level surface, on that the conservative physical quantity is definded as it follows from properties of the closed inexact form). {In the works [15, 32] it was shown a connection of equations for single, double, ... eikonals with the equations of the characteristics, Hamilton equations and so on.}

9. Classification of the physical structures. (Parameters of closed exterior and dual forms)

To obtain the physical structures of given physical field it is necessary to consider the material system which corresponds to this field. In particular, to obtain the thermodynamic structures (fluctuations, phase transitions, etc) one has to analyze the evolutionary relation for the thermodynamic systems, to obtain the gas dynamic ones (waves, jumps, vortices, pulsations) he has to employ the evolutionary relation for gas dynamic systems, for electromagnetic field he must employ a relation obtained from equations for charged particles. Maybe, the physical vacuum is an analogue to such material system in the case of elementary particles. {Some concrete relations are presented in Appendices (2)-(4)}.

The closed forms that correspond to physical structures are generated by the evolutionary relation having parameter p which defines a number of interacting balance conservation laws. Therefore, the physical structures can be classified by the parameter p. The other parameter is a degree of the closed forms. As it was shown above, the evolutionary relation of power p may generate the closed forms of degree $0 \leq k \leq p$. Therefore, the physical structures can be classified by the parameter k as well. The closed exterior forms of the same degree realized in spaces of different dimensions prove to be distinguishable because a dimension of the pseudostructures, on which the closed forms are defined, depend on the space dimension. As a result, the space dimension also specifies the physical structures. This parameter determines properties of the physical structures rather then their type.

Hence, from the analyses of the evolutionary relation one can see that a type and properties of the physical structures (and accordingly of physical fields) for a given material system depend on a number of interacting balance conservation laws p, on the degree of realized closed forms k, and on a space dimension. By introduction a classification with respect to p, k, and a space dimension we can understand an internal connection of various physical fields and interactions (see Appendix 5).

10. Conclusions

Thus, the mathematic tool that bases on properties of nonintegrable exterior differential forms enables one to understand a role of the conservation laws in the evolutionary processes and disclose a mechanism of formation of the physical fields. Because of nonconsistence of the external effects the balance conservation laws (energy, linear momentum, angular momentum, and mass) for the material systems prove to be noncommutative (*it follows from the nonidentity of the evolutionary relation obtained from equations of the balance conservation laws*). And then, because of noncommutativity of the balance conservation laws, a state of the material system turns out to be nonequilibrum, and this is the cause of the evolutionary process (*a value of the internal force is determined by a commutator of the noninte-*

grable form that enters into the evolutionary equation). Under some additional conditions that are determined by properties of the material system and realized in the physical processes, it is possible a conjugation of the balance conservation laws (*a degenerate transform corresponds to this case*), and it is an indicator of a creation of the physical structures (transformation of internal forces into potential ones). And in the material system this reveals as arising some measurable formations: fluctuations, pulsations, waves, vortices, particles and so on (*characteristics of formations arisen are determined by ones of the nonintegrable exterior forms, their commutators and conjugation condition as well as by characteristics of the closed exterior forms and dual forms*).

It was shown that the physical structures which constitutes the physical fields are generated by the material systems. This process is accompanied with a formation of the pseudometric and metric spaces, and the conservation laws govern this processes.

At this point it worth underline that, in spite of these results are qualitative ones, they can help while studying the evolutionary processes in the concrete material systems and while investigation of concrete physical fields and their formations (see Appendices (2)-(6)).

The mathematical theory that explains the evolutionary process in the material systems and a mechanism of formation of the physical fields may be regarded as the basis of the qualitative evolutionary theory of fields. An investigation carried out allows to conclude that axioms provided the basis of the existing theories are the conjugation conditions of the balance conservation laws for the material systems, which generate the physical fields. {It worth emphasize that we used a mathematic tool which bases on properties of the **nonintegrable exterior differential forms**, i.e. forms defined on the nondifferentiable manifolds. A specific property of these forms is a presence of nonidentical relations and degenerate transforms (a transition from the accompanying frame of reference to the inertial one)}.

Appendix 1

Exact conservation laws as the basis of existing field theories. (Closed exterior forms in field theory)

As the closed exterior differential form corresponds to the conservation laws for physical fields and potentials, they may be exploited for description of physical fields. A dependence of properties of exterior and dual to them forms on a degree of the form, space dimension, complex exterior and interior structure of the forms, various conditions and manners of conjugation provide a diversity of physical structures that format physical fields. It may be shown that essentially all physical theories that describe physical fields are based on operators which are reduced to operators acting on the closed exterior forms. If in addition to the exterior differential d to introduce operators: 1) δ for an operator that takes the form of degree $(p+1)$ to that of degree p, 2) δ' for an operator of cotangent transforms, 3) Δ for the transform $d\,\delta - \delta\,d$, 4) Δ' for the transform $d\,\delta' - \delta'\,d$, then the operators of field theory that act on the differential forms can be written in terms of these operators. The operator δ corresponds to Green's operator, the operator δ' corresponds to the operator of canonical transform, Δ does to the d'Alembert operator in the 4-dimension space, and Δ corresponds to the Laplace operator [10, 14]. Eigenvalues of these operators reveal themselves as conjugation conditions for elements of the differential forms. In the tensor equations the skew symmetric tensors correspond to the closed forms.

All existing field theories are based on the exact conservation laws. The essence of these theories are invariant and metric properties of the closed exterior differential forms that correspond to the exact conservation laws. (In particular, it may be verified that equations of existing field theories are those that have solutions being the closed or dual to them forms). Into all existing field theories there were introduced supplementary conditions of invariance or covariance which appears to be the closure conditions for the exterior or dual forms. Essentially all existing field theories contain elements of noninvariance, i.e. they are based either on functionals that are not identical invariants (such as Lagrangian, action functional, entropy) or on equations (differential, integral, tensor, spinor, matrix and so on) that have no identical invariance (integrability or covariance). Such elements of noninvariance are, for example, nonzero value of the curvature tensor in the Einstein theory [20], the indeterminacy principle in the Heisenberg theory, the torsion in the theory by Weyl [20], the Lorentz force in electromagnetic theory [21], an absence of the general integrability of the Schrődinger equations, nonmetric cross-sections in the Yang-Mills theory, the Lagrange function in the variational methods, an absence of the identical integrability on equations of the mathematical physics and that of identical covariance of the tensor equations, and so on. Only if we assume elements of noncovariance, we can obtain the closed **inexact** forms. Precisely such closed forms can correspond to the physical structures that constitute the physical fields.

However, the existing field theories are invariant ones because they are provided with additional conditions, i.e. the conjugation conditions under which the invariance or covariance requirements have to be obeyed. Examples of such conditions may be the identity relations: canonical relations in the Schrődinger equations, gauge invariance in electromagnetic theory, commutator relations in the Schrődinger theory,

Christoffel's coefficients of connectivity and identity relations by Bianchi in the Einstein theory, cotangent bundles in the Yang-Mills theory, the Hamilton function in the variational methods, the covariance conditions in the tensor methods, the characteristic relations (integrability conditions) in equations of mathematical physics, etc. It can be shown that these invariance conditions are that of closure for the exterior or dual forms.

As all existing field theories are subjected to the invariance conditions, equations of these theories have only invariant solutions, i.e. those that can be expressed in terms of the closed or dual to them forms and correspond to physical fields. Possible noninvariant solutions, that may be realized if the invariance conditions are not imposed, are not accounted for. From this standpoint it needs to be recognized two types of equations or methods of invariant field theory. A principal distinction of these two types consists in the following. One type has only invariant solutions, the other one, if the invariance conditions to be omitted, may have noninvariant solutions (functionals) that have a physical sense. Equations of the tensor, spinor, matrix or variational forms, the group theory methods, the transformation theory, theory of symmetries, the bundle theory can be assign to the first type. To the second type we may relate the so-called equations of mathematical physics, namely, differential and integral equations that describe physical processes. As it will be shown later, noninvariant solutions to the second type equations play a governing role in description of a mechanism of the physical structure creation. At the same time, just equations and methods of the first type (equations by Maxwell, Schrődinger, Dirac, Einstein, field theory by Yang-Mills, the group theory, theory of symmetries and so on) allow one to discover a great variety of physical structures, describe physical fields, and understand regularities of the physical world.

The field theories that are based on the exact conservation laws allow to describe the physical fields. However, because these theories are invariant ones they cannot answer the question about a mechanism of creating physical structures which format the physical fields. The answer may be done only by theory where the closure conditions of the forms were not introduced. These conditions have to be realized by themselves without external forcing. A realization of such conditions means a creation of the closed form, and it will correspond to the conservation law and point to appearance of the physical structure. It is evident that an answer to a question concerning a mechanism of creation of the physical structures may be given only by the evolutionary theory. As it was shown above, such a theory is the evolutionary theory which bases on the balance conservation laws for the material systems.

Appendix 2

Analyses of principles of thermodynamics

The thermodynamics is based on the first and second principles of thermodynamics, which were introduced as postulates [22]. Let us show that the first principle of thermodynamics follows from the balance conservation laws for energy and linear momentum and is valid for the case when the heat influx is the only external action. It appears to be nonidentical relation, and it points out that the balance conservation laws are noncommutative and a state of thermodynamic system is nonequilibrum one. The second principle of thermodynamics with the equality sign is obtained from the first that under a realization of the integrability condition, when a role of the integrating factor plays the temperature, and it corresponds to a locally equilibrum state of the system while the temperature is realized. The second principle of thermodynamics with the inequality sign takes into account a presence of some actions other than the heat influx.

As it is well known, the first principle of thermodynamics can be presented in the form

$$dE + \delta w = \delta Q,$$

where dE is a change of energy of the thermodynamic system, δw is a work done by the system (this means that δw is expressed in terms of the system parameters), δQ is an amount of heat putted into the system (i.e. external action on the system). As the term δw has to be expressed in terms of the system parameters and it specifies a real (rather then virtual) change, then it can be designated by dw, and hence, the first principle of thermodynamics will take the form

$$dE + dw = \delta Q. \tag{1}$$

What is a difference between the first principle of thermodynamics and the balance conservation laws? The balance conservation law for thermodynamic system can be written as

$$dE = \delta Q + \delta G, \tag{2}$$

where by δG we designate energetic actions with the exception of heat influx. For thermodynamic system the balance conservation law for linear momentum (a change of linear momentum of the system in its dependence on the force mechanical action on the system) can be written as

$$dw = \delta W. \tag{3}$$

Here δW signifies a force (mechanical) action on the system (for example, external compression of the system, an influence of boundaries and so on).

If to sum relations (2) and (3), then one obtains the relation

$$dE + dw = \delta Q + \delta G + \delta W, \tag{4}$$

which is just the evolutionary relation for the thermodynamic system.

By comparison the relation (4), that follows from the balance conservation laws for energy and linear momentum, with the relation (1), one can see that they coincide if the heat influx is the only external action on the thermodynamic system ($\delta W = 0$ and $\delta G = 0$).

Thus, the first principle of thermodynamics is obtained from the balance conservation laws for energy and linear momentum. This is analogous to the evolutionary relation.

The significance of the first principle of thermodynamics, as well as of the evolutionary equation, is that it reveals a nature of interactions of two balance conservation laws (rather then it only corresponds to the conservation law for energy). As δQ is not a differential (closed form) then the relation (1), which correspond to the first principle of thermodynamics, as well as the evolutionary equation appear to be the nonidentical nonintegrable relation. This points to the noncommutativity of the balance conservation laws (for energy and linear momentum) and to nonequilibrum state of the thermodynamic system. As it follows from the analyses of the evolutionary relation, a transition to the locally equilibrum state has to correspond to the realization of additional condition (i.e. the integrability condition) under which this relation turns out to be identical one. Such an identical relation is just a relation which corresponds to the second principle of thermodynamics.

Let us consider the case when the work performed by the system is carried out through the compression. Then $dw = p\,dV$ (here p is the pressure and V is the volume) and $dE + dw = dE + p\,dV$. As it is known, the form $dE + p\,dV$ can become a differential if there is the integrating factor (a quantity which depends only on the characteristics of the system) $1/\theta = pV/R$ which is named as the thermodynamic temperature T [22]. In this case the form $(dE + p\,dV)/T$ turns out to be a differential (interior) of some quantity that referred to as entropy S:

$$(dE + p\,dV)/T = dS, \tag{5}$$

(although the form $dE + p\,dV$ consists of differentials, in the general case without the integrating factor it is not a differential because of that its terms depend on different variables, namely, the first term is determined by variables that specifies the internal construction of elements, and the second term depends on variables that specify an interaction between elements, for example, a pressure). If the integrating factor $1/\theta = T$ to be realized, that is, the relation (5) proves to be satisfied, then from the relation (1), which corresponds to the first principle of thermodynamics, it follows

$$dS = \delta Q/T. \tag{6}$$

This is just the second principle of thermodynamics for reversible processes. It takes place when a heat influx is the only action on the system. If besides the heat influx the system undergos any mechanical forcing δW (for example, an influence of boundaries), then according to the relation (4) from the relation (5) we obtain

$$dS = (dE + p\,dV)/T = (\delta Q + \delta W + \delta G)/T \tag{7}$$

from which it follows, that

$$dS > \delta Q/T \tag{8}$$

which corresponds to the second principle of thermodynamics for irreversible processes.

The relations (6), (8) which can be written as

$$dS \geq \delta Q/T, \tag{9}$$

express the second principle of thermodynamics. (It is well to bear in mind that the differentials in the relations (5), (6), (8), (9) are not total ones. They are satisfied only in presence of the integrating factor, namely, the temperature which depends on the system parameters).

Thus, the first principle of thermodynamics is obtained from the balance conservation laws for energy and linear momentum, and the second principle of thermodynamics does from the first one. The second principle of thermodynamics with the equality sign follows from the first principle under the fulfillment of the condition of integrability, i.e. a realization of the integrating factor (temperature). (This transition corresponds to that from the nonequilibrum state to the locally equilibrum state. Phase transitions, the origin of fluctuations, etc are examples of such transitions). And the second principle of thermodynamics with the inequality sign takes into account a presence in the real processes other actions besides the heat influx.

In the case examined above a differential of entropy (rather then entropy itself) becomes the closed form. {In this case entropy manifests itself as the thermodynamic potential, namely, the function of state. To the pseudostructure there corresponds the state equation which determines the temperature dependence on the thermodynamic variables}. For entropy to be the closed form itself, a one more condition has to be realized. Such a condition may be a realization of the integrating direction, an example of that is the sound speed: $a^2 = \partial p/\partial\rho = \gamma\, p/\rho$. In this case it is valid the equality $ds = d(p/\rho^\lambda) = 0$ from which it follows that entropy $s = p/\rho^\lambda = const$ is the closed form (of zero degree). {But it does not mean that a state of the gaseous system is identically isoentropic one. Entropy

is constant only along the integrating direction (for example, on the adiabatic curve or on the front of sound wave), whereas in the direction being normal to the integrating direction the normal derivative of entropy has a break}.

It worth underline that both temperature and the sound speed are not continuous thermodynamic variables. They are variables which are realized in the thermodynamic processes if the thermodynamic system has any degrees of freedom. One may see an analogy between temperature and the sound speed: temperature is the integrating factor and the sound speed is the integrating direction. {Notice that in actual processes a total state of the thermodynamic system is nonequilibrum one and a commutator of the form $dE + pdV$ is nonzero. A quantity that is described by commutator and acts as internal force may grow. Prigogine [19] defined this as the "production of the excess entropy". Just this increase of the internal force is perceived as the growth of entropy in the irreversible processes}.

The closed static system, if left to its own devices, may tend to a state of total thermodynamic equilibrum. This corresponds to tending of the system functional to its asymptotic maximum. In the dynamical system the tending of the system to a state of total thermodynamic equilibrum may be violated by dynamical processes and transitions to a state of local equilibrum.

Appendix 3

Influence of noncommutativity of the balance conservation laws on a development of instability

A noncommutativity of the balance conservation laws, that leads to the emergence of internal forces and an appearance of the nonequilibrum, is a cause of development of instability in the material systems. Hence, to study a cause of development of instability, it is necessary to examine the evolutionary relation obtained from the balance conservation laws and analyze a commutator of the nonintegrable form entered into this relation.

For example, we take the simplest gas dynamical system, namely, a flow of the ideal (nonviscous, heat nonconductive) gas [23]. Suppose, that gas is the thermodynamic system in the local equilibrum (whereas the gas dynamical system may be in the nonequilibrum state). This means that the following relation is satisfied [22]

$$Tds = de + pdV, \tag{1}$$

here T, p and V are the temperature, the pressure, and the gas volume respectively, s, e are entropy and the internal energy per unit volume of the gas.

Let us introduce two frames of reference: the inertial one, which is not connected with the material system, and the accompanying system that is connected with a manifold formatted by trajectories of elements of the material system. (As examples these may be both Euler's and Lagrange's systems of coordinates).

In the inertial system of coordinates the Euler equations are the balance conservation laws for energy, linear momentum and mass of the ideal gas [16]. The balance conservation law for energy of the ideal gas can be written as

$$\frac{Dh}{Dt} - \frac{1}{\rho}\frac{Dp}{Dt} = 0,$$

where D/Dt is the total derivative with respect to time (if to designate the spatial coordinates by x_i and velocity components by u_i, then $D/Dt = \partial/\partial t + u_i\partial/\partial x_i$), h is the entalpy of the gas. Expressing the entalpy in terms of the internal energy e with the help of the formula $h = e + p/\rho$ and using the relation (1) we can reduce the equation of balance conservation law for energy to the form

$$\frac{Ds}{Dt} = 0. \tag{2}$$

And respectively, the equation of balance conservation law for momentum can be presented as [16, 24]

$$\operatorname{grad} s = (\operatorname{grad} h_0 - \mathbf{U}\times\operatorname{rot}\mathbf{U} + \mathbf{U}\times\mathbf{F} + \partial\mathbf{U}/\partial t)/T, \tag{3}$$

where $\mathbf{U}$ is the velocity of the gas particle, $h_0 = (\mathbf{U}\cdot\mathbf{U})/2 + h$, $\mathbf{F}$ is the mass force.

As the total derivative with respect to time is that along the trajectory, then in the accompanying frame of reference the equations (2), (3) take the form:

$$\frac{\partial s}{\partial \xi^1} = 0, \tag{4}$$

$$\frac{\partial s}{\partial \xi^\nu} = A_\nu, \quad \nu = 2, \dots, \tag{5}$$

where ξ^1 is the coordinate along the trajectory, $\partial s/\partial\xi^\nu$ is the left-hand side of the equation (3), and A_ν is obtained from the right-hand side of the relation (3). {In the common case when gas is nonideal the equation (2) can be written in the form

$$\frac{\partial s}{\partial \xi^1} = A_1, \tag{6}$$

where A_1 is the expression which depends on the energetic actions. In the case of ideal gas $A_1 = 0$ and the equation (6) transforms into (4). In the case of viscous heat-conductive gas, described by a set of the Navier-Stokes equations, in the inertial coordinate system can be written in the form [16]

$$A_1 = \frac{1}{\rho}\frac{\partial}{\partial x_i}\left(-\frac{q_i}{T}\right) - \frac{q_i}{\rho T}\frac{\partial T}{\partial x_i} + \frac{\tau_{ki}}{\rho}\frac{\partial u_i}{\partial x_k}. \tag{7}$$

Here q_i is the heat flux, τ_{ki} is the viscous stress tensor. In the case of reacting gas there are added additional terms connected with the chemical nonequilibrum.

The equations (4) and (5) can be convoluted into the equation

$$ds = \omega, \tag{8}$$

where $\omega = A_\mu d\xi^\mu$ is the differential form of the first degree (here $\mu = 1, \nu$).

The relation (8) is the evolutionary relation for the gas dynamical system (in the case of the local thermodynamic equilibrum). Here $\psi = s$. {It worth notice that in the evolutionary relation for the thermodynamic system it is examined a dependence of entropy on the thermodynamic variables (see the relation (1)), but in the evolution relation for the gas dynamical system the entropy dependence on the space-time variables is considered}. If the relation (8) be identic one (if the form ω be the closed form, i.e. a differential), then one can obtain differential of entropy s and find entropy as a function of space-time coordinates. Just this entropy will be the gas dynamical function of state, a presence of which will point to that a state of the gas dynamical system is locally equilibrum. And if the relation (8) will not be identical, then the differential of entropy cannot be defined a differential of entropy s. This will point to an absence of the gas dynamical function of the state and nonequilibrum state of the system. Such nonequilibrum is a cause of a development of instability.

Because of that nonequilibrum is produced by internal forces which are described by a commutator of the form ω, then it becomes evident that a cause of the gas dynamical instability is something that contributes to a commutatior of the form ω. Without an accounting for terms which are connected with a deformation of the manifold formatted by trajectories, the commutator can be written as

$$K_{1\nu} = \frac{\partial A_\nu}{\partial \xi^1} - \frac{\partial A_1}{\partial \xi^\nu}. \tag{9}$$

From the analyses of the expression A_ν and with taking into account that $A_1 = 0$, one can see, that into commutator there contribute terms which are related to the multiple connectivity of the flow domain (the second term of the expression for A_ν), nonpotentiality of the external forces (the third term) and a nonstationarity of the flow (the forth term). {In the general case the terms connected with the transport phenomena and the physical and chemical processes contribute to the commutator (9)}. These factors lead to the origin of internal forces, to nonequilbrum state and to the development of instability of various kinds. And yet for every kind of instability one can find an appropriate term in the commutator of the nonintegrable form, which is responsible for this kind of instability. {Under this process it is also necessary to consider the evolutionary relations which the balance conservation laws for angular momentum and mass correspond to}. Thus, there is an unambiguous connection between a kind of instability and the terms that contribute into the commutator of the nonintegrable form in the evolutionary relation.

As it was shown, under the realization of the additional degrees of freedom, a development of instability may lead to origin of the physical structures when the internal forces transform into the potential ones. Such gas dynamical structures are shocks, shock waves, turbulent pulsations and so on. Additional degrees of freedom are realized as the condition of the degenerate transform, namely, vanishing of determinants, Jacobians of transforms, etc. For example, such conditions are justified either on characteristics (determinant of coefficients at the normal derivatives vanishes), or at the singular points (Jacobian is equal to zero) on the envelop of the characteristics of the Euler equations, or at the singular points of the Navier-Stokes equations (when the viscous gas is considered).

Let as analyze what kinds of instability and what gas dynamical structures may originate under given forcing.

1). *Shock, break of diaphragm and others.* The instability originates because of nonstationarity. The last term in the equation (3) gives a contribution into the commutator. In the case of ideal gas, whose flow is described by equations of the hyperbolic type, a transition to the locally equilibrum state is possible on the characteristics and their envelops. The corresponding structures are weak shocks and shock waves.

2).*Flow around bodies by ideal (unviscous, thermal unconductive) gas. Action of the nonpotential body forces.* The instability develops because of the multiple connectivity of the flow domain and the nonpotentiality of the body forces. A contribution into the commutator has come from the second and third terms of the right-hand part of the equation (3). As the gas is ideal one and $\partial s/\partial \xi^1 = A_1 = 0$, that is there is no contribution into every fluid particle, then the instability of convective type develops. For $U > a$ (U is the velocity of the gas particle, a is the speed of sound) a set of equations of the balance conservation laws belongs to the hyperbolic type and hence a transition to the locally equilibrum state is possible on the characteristics and the envelops of characteristics as well, and weak shocks and shock waves are the structures of the system. If $U < a$ when the equations are of elliptic type, such a transition is possible only at singular points. The structures, originated because of the convection, are of the vortex type. Under long forcing the large-scale structures can be produced.

3. *Boundary layer.* The instability originates because of the multiple connectivity of the domain and the transport phenomena (an influence of viscosity and thermal conductivity). Contributions into the commutator produce the second term in the right-hand part of

the equation (3) and the second and third terms in the expression (7). A transition to the locally equilibrum state is allowed at the singular points. As in this case $\partial s/\partial \xi^1 = A_1 \neq 0$, that is, forcing acts on every gas particle singly, then a development of instability and transitions to the locally equilibrum state are allowed only in single fluid particle. Hence, the structures originated behave as pulsations. These are the turbulent pulsations.

In worth notice that separating of some formation from the local domain is accompanied by a production of the discontinuous surfaces (the contact discontinuities). Unlike shocks and shock waves these discontinuities do not propagate relative to the material system.

Appendix 4

Electromagnetic field

We will show how it may be obtained the evolutionary relation for the system which generates the electromagnetic field and what are specific features of this relation.

As it is known [8], the electromagnetic field can be presented by some 2-form and its dual one. The Maxwell equations appear to be reduced to that the both forms are closed forms. Let us analyze when the closure conditions are satisfied.

If to utilize the Lorentz force $\mathbf{F} = \rho(\mathbf{E} + [\mathbf{U} \times \mathbf{H}]/c)$, then a local variation of energy and linear momentum of the charged substance may be written respectively as [17]: $\rho(\mathbf{U} \cdot \mathbf{E})$, $\rho(\mathbf{E} + [\mathbf{U} \times \mathbf{H}]/c)$. Here $\mathbf{E}, \mathbf{H}$ are respectively the electric and magnetic strengths of the field, ρ is the charge density, $\mathbf{U}$ is the velocity of the charged substance. These variations of energy and linear momentum are caused by energetic and force actions and are equal to values of these actions. If to denote these actions by Q^e, $\mathbf{Q}^i$, then the balance conservation laws can be written as follows:

$$\rho\,(\mathbf{U} \cdot \mathbf{E}) = Q^e,$$
$$\rho\,(\mathbf{E} + [\mathbf{U} \times \mathbf{H}]/c) = \mathbf{Q}^i. \qquad (1)$$

After elimination of the characteristics of the material system (charged substance) ρ and $\mathbf{U}$ by application of the Maxwell-Lorentz equations [17], the left-hand sides of the equations (1) can be expressed only through the strengths of the electromagnetic field and then one can write the equations (1) in the form:

$$c\,\mathrm{div}\mathbf{S} = -\frac{\partial}{\partial t} I + Q^e, \qquad (2)$$

$$\frac{1}{c}\frac{\partial}{\partial t}\mathbf{S} = \mathbf{G} + \mathbf{Q}^{\mathbf{i}}, \qquad (3)$$

where $\mathbf{S} = [\mathbf{E} \times \mathbf{H}]$ is the Pointing vector, $I = (E^2 + H^2)/c$, $\mathbf{G} = \mathbf{E}\,\mathrm{div}\mathbf{E} + \mathrm{grad}(\mathbf{E} \cdot \mathbf{E}) - (\mathbf{E} \cdot \mathrm{grad})\mathbf{E} + \mathrm{grad}(\mathbf{H} \cdot \mathbf{H}) - (\mathbf{H} \cdot \mathrm{grad})\mathbf{H}$.

The equation (2) is widely utilized while description of the electromagnetic field and a calculation of energy and the Pointing vector. And the equation (3) does not commonly be taken into account. Actually, the Pointing vector $\mathbf{S}$ has to obey to two equations, which can be convoluted into the **relation**

$$d\,\psi = \omega, \qquad (4)$$

where 2-form $d\,\psi$ corresponds to the vector $\mathbf{S}$ and coefficients of the form ω^2 (the upper subscript shows a degree of the form) are the right-hand parts of the equations (2), (3). It is just the evolutionary relation for the system of charged particles that generates the electromagnetic field.

From the equations (2), (3) or from the evolutionary relation one can find the Pointing vector as some preservable measured physical quantity only if these equations are conjugated ones, that is, if a commutator formed by mixed derivatives (it is just a commutator of the form ω^2) is equal to zero. And if the commutator is nonzero, then the right-hand side is not a differential and the Pointing vector is some functional. Under what conditions can the Pointing vector be formatted as a measurable quantity?

Let us choose the local coordinates l_k in such a way that one direction l_1 coincides with a direction of the vector $\mathbf{S}$. As this chosen direction coincides with a direction of the vector $\mathbf{S} = [\mathbf{E} \times \mathbf{H}]$ and hence is normal to the vectors $\mathbf{E}$ and $\mathbf{H}$, then one obtains that $\mathrm{div}\mathbf{S} = \partial s/\partial l_1$, where S is the module of $\mathbf{S}$. And in addition, the projection of the vector $\mathbf{G}$ on the chosen direction turns out to be equal to $\partial I/\partial l_1$. As the result, after separating from the vector equation (3) its projection on the chosen direction, the equations (2), (3) can be written as

$$\frac{\partial S}{\partial l_1} = -\frac{1}{c}\frac{\partial I}{\partial t} - \frac{1}{c}Q^e, (5 \qquad (5)$$

$$\frac{\partial S}{\partial t} = c\,\frac{\partial I}{\partial l_1} - c\mathbf{Q}'^i, \qquad (6)$$

$$0 = -\mathbf{G}'' - c\mathbf{Q}''^i.$$

Here the prime relates to the direction l_1, double primes do to the other directions. Under the condition $\partial l_1/\partial t = c$ from the equations (5), (6) it is possible to obtain a relation in the differential forms

$$\frac{\partial S}{\partial l_1}dl_1 + \frac{\partial S}{\partial t}dt = -\left(\frac{\partial I}{\partial l_1}dl_1 + \frac{\partial I}{\partial t}dt\right) - (Q^i dt + \mathbf{Q}'^e dl_1).(7)$$

As the second brace in the right-hand side is not a differential (the energetic and force actions have distinguished nature and cannot be conjugated), then one can obtain a closed form only if the right-hand side vanishes:

$$\left(\frac{\partial I}{\partial l_1}dl_1 + \frac{\partial I}{\partial t}dt\right) - (O^i\,dt + \mathbf{Q}'^e\,dl_1) = 0 \qquad (8)$$

that is

$$\frac{\partial I}{\partial t} = \mathbf{Q}^{\prime e}, \quad \frac{\partial I}{\partial l_1} = Q^i. \tag{9}$$

In this case $dS = 0$ and the module of the Pointing vector S proves to be the closed form, i.e. a measurable quantity. And the integrating direction (pseudostructure) will be

$$-\frac{\partial S/\partial t}{\partial S/\partial l_1} = \frac{dl_1}{dt} = c. \tag{10}$$

Thus, the constant c, that was introduced into the Maxwell equations, is defined as the integrating direction. From the expressions (9) it is evident, that in this case the local energetic and force actions on the material system (charged substance) appear to be transformed into the quantities of the electromagnetic field, namely, energy and linear momentum of the electromagnetic wave that propagates with the light speed c, which value is defined by the condition (10). One can see, that the constant c in the Maxwell equation is the speed of the electromagnetic wave and it is defined as the integrating direction.

Appendix 5

On interactions

As it was shown above, a type of the physical structures (and, accordingly, the physical fields) generated by the evolutionary relation depends on a degree of the exterior forms p and k (here p is a degree of the nonintegrable form of the evolutionary relation which is connected with a number of the interacting balance conservation laws, and k is a degree of the closed form generated by the evolutionary relation) and on a space dimension n. By introducing the classification by numbers p, k, n one may understand the internal connection of different physical fields and see a connection between interactions. It is reflected in the table presented below.

In the table names of the particles created are given. Numbers placed near particle names correspond to the space dimension. In the curly brackets the sources of interactions are presented. In the lower row we point out the massive particles created by interactions (the exact forms of zero degree obtained by sequent integrating of the forms of degree p correspond to these particles). From the table one can see a correspondence between the degree k of the closed forms being realized and a type of interactions. Thus, $k = 0$ corresponds to the strong interaction, $k = 1$ does to the weak one, $k = 2$ corresponds to the electromagnetic interaction, and $k = 3$ does to the gravitational interaction. As a result, we obtain that a type of interaction and a type of the created particles is defined by the degree (k) of the closed forms realized, and properties of the particles are governed by the degree (p) of the evolutionary equation, namely, by a number of the interacting balance conservation laws, and the space dimension. The last property is connected with that the closed forms of equal degrees k, but obtained from the evolutionary relations acting in spaces of different dimensions n (the values of p are different), are distinguished as they are defined on the pseudostructures of different dimensions (the dimension of the pseudostructure $(n+1-k)$ depends on the dimension of the initial space n). For this reason the realized physical structures with equal degrees k of the closed forms are distinguishable. A connection between a type of interactions and the conservation laws may be seen by a comparison of the first and last columns. In the last column the interacting balance conservation laws are pointed out. The arrows show that the conservation laws presented in given cell are added to that from lower cells. Notice that for $k = 0$ in the space of zero dimension there is no the momentum. This manifests it self beginning with the space of the dimension 1 (in the forms of degree $k = 0$ energy and momentum are formatted independently). For $k = 0$ energy and momentum are nonconjugate. The forms dual to them are respectively time and coordinates (time and coordinates have different nature because time is dual to energy and coordinates are dual to linear momentum). Energy and time as well as linear momentum and coordinate do not commutate within the framework of the same form because they relate to different forms: exterior and dual ones. (The commutative relations $\hat{q}\hat{p} - \hat{p}\hat{q} = \imath\hbar$ reflect this fact. The left-hand side of the commutative relations is analogous of the commutator value of the nonintegrable form of zero degree, and the right-hand side is equal to its value at the point in time of the realization of the closed zero degree form, the imaginary unit points to the transverse direction with respect to the pseudostructure). The closed exterior form of degree $k = 1$ corresponds to a conjugation of energy and momentum (for $k = 1$ energy and momentum prove to be the simultaneously measurable quantities).

{In the table a single cycle of formation of the physical structures is presented. It contains four levels to every of those it corresponds a proper value p $(p = 0, 1, 2, 3)$ and the space dimension n. The structures formatted in the preceding cycle serves as a source of interactions for the first level of a new cycle. The sequential cycles reflect properties of the sequentially embedded material systems. And some given level has specific properties which are inherent in the same levels of the other cycles. For example, it may be seen by comparison of the cycle described and the cycle where conductors, semiconductors, dielectrics and neutral elements are sequentially correspond to the exact forms. Properties of elements of the third level, namely, neutrons in one cycle and dielectrics in the other coincide with those of the so-called "magnetic monopole" [25, 26]}.

TABLE

interaction	n \ k \ p	i+0 **0**	i+1 **1**	i+2 **2**	i+3 **3**	**balance conserv. laws**
gravitation	**3**				**graviton** ⇑ {electron +proton +neutron +photon (neutrino +quant)?	mass
electro-magnetic	**2**			**photon 2** ⇑ {electron+ proton+ neutrino} {quant}?	**photon 3**	angular momentum ↑
weak	**1**		**neutrino 1** ⇑ {electron +quant }	**neutrino 2**	**neutrino 3**	linear momentum ↑
strong	**0**	**quant 0** ⇑ (quarks?)	**quant 1** muons? gluons?	**quant 2**	**quant 3**	$p = 0$ energy+ time or $p > 0$ momentum +coordin.
particles material (nuclons?)	exact forms	**electron**	**proton**	**neutron**	**deuteron ?**	

Appendix 6

A formation of the metric space

As it was shown above, a noncommutativity of the balance conservation laws and a transition from those to the exact conservation laws explain a mechanism of origin of the physical structures. And as the origin of the physical structures is connected with a formation of the pseudostructures, then by analyzing a mechanism of formation of the physical structures one can understand a mechanism of formation of the pseudometric and metric spaces. {Recall, that the inexact closed forms correspond to the physical structures and pseudostructures. and the exact forms correspond to elements of the material system and to the metric spaces}. It is useful to note some properties of the manifolds.

Assume, that on the manifold one can choose any system of coordinates with the basis $\mathbf{e}_\mu$ and to set up the metric forms of manifold [20]: $(\mathbf{e}_\mu\, \mathbf{e}_\nu)$, $(\mathbf{e}_\mu\, dx^\mu)$, $(d\,\mathbf{e}_\mu)$. The metric forms and their commutators define metric and differential characteristics of manifold. If the metric forms are closed (commutators are equal to zero), then the metric $g_{\mu\nu} = (\mathbf{e}_\mu \mathbf{e}_\nu)$ is defined, and the results of displacement over manifold the point $d\mathbf{M} = (\mathbf{e}_\mu dx^\mu)$ and a unit vector $d\mathbf{A} = (d\mathbf{e}_\mu)$ are independent of the path of displacement (the path of integration). The closed metric forms define the structure of the manifold, and the commutators of the metric forms determine such characteristics of the manifold as bend, torsion, curvature (if the commutators are nonzero, then the results of displacement over manifold of a point or the unit vector depend on the path of displacement). An example of manifold with the closed metric forms is the differentiable manifold whose metric and differential characteristics prove to be consistent [10].

A role of the differential characteristics of the manifold may play the connectivities [20] $\Gamma^\rho_{\mu\nu}$, $(\Gamma^\rho_{\mu\nu} - \Gamma^\rho_{\nu\mu})$, $R^\mu_{\nu\mu\sigma}$, which are components of a commutator of the metric forms.

As it is known [20], these commutators for the Euclidean manifold are equal to zero. In the case of the Riemann manifold the commutator of the metric form of degree two is nonzero: $R^{\mu}_{\nu\rho\sigma} \neq 0$.

If the exterior differential forms are defined on manifolds whose metric forms are nonclosed, then, as it was pointed out, the commutators of the metric forms will enter into the commutators of the exterior differential forms. In particular, components of the commutator of the external form of degree one $\theta = a_\alpha\, dx^\alpha$ can be written in terms of connectivities as follows:

$$K_{\alpha\beta} = \left(\frac{\partial a_\beta}{\partial x^\alpha} - \frac{\partial a_\alpha}{\partial x^\beta}\right) + (\Gamma^\sigma_{\beta\alpha} - \Gamma^\sigma_{\alpha\beta})\, a_\sigma. \qquad (1)$$

It is evident, that the commutator of the exterior form consists of two terms. The first one (the first parentheses) depends on coefficients of the exterior form, and the second term does on the differential characteristics of the manifold. It is a typical feature for the commutator of the exterior forms of other degrees as well. Because of this feature the topologic properties of commutators of the exterior forms are manifested: they can realize a mutual relation between the exterior form and the basis, namely, the metric form of manifold. The other specific feature is that terms in the commutator have the different nature, i.e. one term depends on coefficients of the exterior form, and the other depends on the basis. Such terms cannot be equal identically, and hence they cannot make the commutator to be zero. This means that the exterior forms, defined on manifolds with nonclosed metric forms, turns out to be nonclosed (such forms may be called nonintegrable ones in contrast to the nonclosed forms defined on the differentiable manifolds). The above mentioned properties of commutators of the exterior forms enable one to understand a mechanism of formation of the metric spaces. Note, that the material system is the generator of the formatting metric space, and an accompanying manifold is the base.

When derivation the evolutionary relation there were used two spatial objects: the accompanying manifold (connected with the material system) that has no metric structure for real processes and the inertial space (not connected with the material system) which is the metric space. {Note, that the metric space formatted becomes the inertial space of one more degree}.

Assume that the initial inertial space has the dimension $n = 3$. The material system in such a space is subjected to the balance conservation laws, which equations in the accompanying frame of reference turn out to be convoluted to the evolutionary relation with $p = n = 3$:

$$d\,\psi \cong \omega^3, \quad d\,\omega^3 \neq 0. \qquad (2)$$

The form ω^3 is defined on the accompanying manifold, and therefore this form is nonintegrable, that is, its commutator is nonzero (a degree of the form ψ equals 2). {In cosmology and the gravitation theory the equations of ideal fluid are sometimes used [15, 17, 27]. In essence, these equations are the balance conservation laws. However, these equations commonly used in the covariant form [27], that is, the covarince condition is imposed. To study a process of formation of the pseudometric and metric spaces it is necessary to employ equations that are not subjected to the conditions of invariance or covariance}.

A realization of the pseudostructure (an element of the pseudometric space) and an origin of the physical structure, which the closed metric and exterior forms correspond to, is the transition from the nonintegrable form ω^3 to the closed form ω'^3 (this is connected with the degenerate transform). And it is required the following relations have to be satisfied:

$$d_\pi\, \omega'^3 = 0,$$
$$d_\pi\, {}^*\omega'^3 = 0. \qquad (3)$$

In the present case a degree of the closed form is $k = p = 3$, and a dimension of the pseudostructure is $m = n+1-k = p+1-k = 1$. On the pseudostructure from the evolutionary relation (2) it follows the relation

$$d_\pi\, \psi = \omega'^3, \qquad (4)$$

which is identical one because the closed form ω'^3 may be expressed through the interior differential. From this relation it can be defined the form $d_\pi \psi$ which specifies a state of the system and may be referred to as the structural form. (In the case under consideration this is the form of degree 3). It corresponds to the conservation law, because a differential of this form (interior on the pseudostructure) is equal to zero.

A realization of the physical structure (connected with an origin of the physical structure and that the conservation law is fulfilled) is one of the exhibitions of a mechanism of formatting the metric spaces. It worth to underline that the pseudostructure is realized with respect to the inertial frame of reference. (The degenerate transform corresponds to transition from the frame of reference connected with the accompanying manifold to the inertial coordinate system).

With the aim to be more clear we shall put the tensor expressions into correspondence to the exterior forms. We may put a tensor with p lower (covariant) subscripts into correspondence to the external form of degree p defined on the differentiable manifold. As it is known, a differential of the form degree p on the differentiable manifold is the form of degree $p+1$. We may put a tensor with $p+1$ lower subscripts into correspondence to the differential of the form of degree p. By analogy with this we put the tensor expression $K_{\alpha\ldots}$ into correspondence to a differential or to a commutator of the nonintegrable form. With this notation a

commutator of the form ω^3 can be written as $K_{\alpha\beta\gamma\chi}$, where three first subscripts corresponds to a degree of the form, and the fourth one appears while differentiating the form (from this point and further we shall use the Greek subscripts for the accompanying frame of reference and Latin ones for the inertial that). A commutator of the basic metric form which can be denoted by $R_{\alpha\beta\gamma\chi}$ enters into a commutator of the nonintegrable form. We may put the covariant tensors of rank 3, S_{jkl} and T_{jkl}, (its divergence is equal to zero as they corresponds to the closed forms) into correspondence to the closed forms $d_\pi\psi$ and ω'^3 (that are formatted with relevance to the inertial frame of reference). And to the pseudostructure we may put into correspondence the 1-covariant pseudotensor T^i (it corresponds to the closed metric form, i.e. pseudostructure), which is dual to the tensor T_{jkl}[15]: $T^i = {}^*T_{ijk} = \frac{1}{6}\varepsilon^{ijkl}T_{jkl}$ (here $\varepsilon^{ijkl} = e_i e_j e_k e_l \varepsilon_{ijkl}$, where ε_{ijkl} is the completely antisymmetric unit pseudotensor) can be put into correspondence to the pseudostructure. Similarly, by $S^i = {}^*S_{jkl}$ denote the tensor dual to S_{jkl}. Now we introduce the tensor expressions:

$$\mathbf{S}^i_{jkl} = \begin{cases} S_{jkl} \\ S^i \end{cases}, \quad \mathbf{T}^i_{jkl} = \begin{cases} T_{jkl} \\ T^i \end{cases}. \tag{5}$$

{These tensor expressions are not tensors with covariant and contravariant subscripts because, firstly, they combine tensors and pseudotensors, and secondly, in these expressions one cannot rise up and lower subscripts as the metric is not defined as yet}. The tensor expression $\mathbf{S}^i_{jkl}$ is a representation of the physical structure (it corresponds to the structure form on pseudostructure), and the tensor expression $\mathbf{T}^i_{jkl}$ is a representation of the forms ω'^3 and ${}^*\omega'^3$ (they correspond to the external actions processed by the system).

With taking into account the relations (3), the relation (4) can be written in terms of the tensor expressions as

$$\mathbf{S}^i_{jkl} = \mathbf{T}^i_{jkl}. \tag{6}$$

The relation (6) shows that the physical structure (including the pseudostructures) are produced at the expense of external actions processed by the system.

What is the further mechanism of formation of the metric space?

While origin of the physical structure, a quantity, which is described by a commutator of the nonintegrable form ω^3 and acts as internal force, transforms into potential force, which acts in the direction transverse to the pseudostructure. (If a differential of the form ω^3 be zero, that is, the commutators $R_{\alpha\beta\gamma\chi}$ and $K_{\alpha\beta\gamma\chi}$ be equal to zero, then the potential force will be equal to zero). This potential force becomes a new source of noneqilibrum (even without the extra external actions) and may lead to a further formation of the pseudostructures.

As the relation (4) is the identical one, then it can be integrated. Because the form ω'^3 is closed, it is the interior (on the pseudostructure) differential of the form one degree less

$$\omega'^3 = d_\pi\omega^2. \tag{7}$$

From the relations (4), (7) it follows the relation (below, for the sake of convenience, we shall indicate explicitly a degree of the form ψ)

$$d_\pi\,\psi^2 = d_\pi\,\omega^2,$$

which can be integrated (within the accuracy up to the lower degree forms):

$$\psi^2 = \omega^2. \tag{8}$$

This is an integration of the nonidentical evolutionary relation (2) over a single dimensionality which has been formatted.

From the relation (7) one can see that a differential of the form ω^2 is nonzero. The form ω^2 (of degree $p-1=2$) proves to be nonintegrable form (its commutator is nonzero) on the manifold directions remained after integration. To the commutator of the form ω^2 it can be put into correspondence the tensor expression $K^\alpha_{\beta\gamma\chi}$ (three lower subscripts is a degree of the exterior form plus 1, and a single top subscript is the pseudometric dimension formatted). In this case the basic commutator can be written in the form $R^\alpha_{\beta\gamma\chi}$. (If the Bianchi identity [20] is satisfied, then from this tensor it can be obtained the Riemann-Christoffel tensor G^i_{jkl} which corresponds to the Riemann manifold. However it takes place only after the pseudoriemann and Riemann manifolds be completely formatted).

Here it appears some special feature. On the one hand, the form ω^2 obtained turns out to be nonintegrable one, and therefore, it cannot be expressed in terms of differential. And on the other hand, the form ψ^2 in the left-hand side of the relation (8), for to become the structural form, has to become the closed form, namely, the differential:

$$\psi^2 = d\,\psi^1. \tag{9}$$

By comparison of the relations (8) and (9), we get

$$d\,\psi^1 \cong \omega^2, \tag{10}$$

which cannot be identity as the form ω^2 is not expressed through differential.

The nonidentical relation (10) is the relation of the type similar to the initial relation (2), however it is the form of one less degree. We may repeat the analysis like for the relation (2) and get the pseudostructure of one more dimension. By sequent integrating of the nonidentical relations we may obtain the pseudometric space. The closed exterior forms of degrees

$p, p-1, ..., 0$, which are inexact, correspond to this space. A transition to the exact form of zero degree will correspond to a transition to the metric space.

With application of the tensor expressions these transitions can be schematically written in the following form:

$$d\psi \cong \omega^3, \quad d\omega^3 \neq 0 \quad (K_{\alpha\beta\gamma\chi} \neq 0, \ R_{\alpha\beta\gamma\chi} \neq 0) \quad (11)$$

. . . . . .

$m = 1$

$$\mathbf{S}^i_{jkl} = \mathbf{T}^i_{jkl}, \quad (12)$$

$$+d\,\psi \cong \omega^2, \quad \omega^2 \neq 0: \quad (K^\alpha_{\beta\gamma\chi} \neq 0, R^\alpha_{\beta\gamma\chi} \neq 0) \quad (13)$$

. . . . . .

$m = 2$

$$\mathbf{S}^{ij}_{kl} = \mathbf{T}^{ij}_{kl} \quad (14)$$

$$d\,\psi \cong \omega^1, \quad \omega^1 \neq 0: \quad (K^{\alpha\beta}_{\gamma\chi} \neq 0, R^{\alpha\beta}_{\gamma\chi} \neq 0) \quad (15)$$

. . . . . .

$m = 3$

$$\mathbf{S}^{ijk}_l = \mathbf{T}^{ijk}_l \quad (16)$$

$$d\,\psi \cong \omega^0, \quad \omega^0 \neq 0: \quad (K^{\alpha\beta\gamma}_\chi \neq 0, R^{\alpha\beta\gamma}_\chi \neq 0) \quad (17)$$

. . . . . .

$m = 4$

$$\mathbf{S}^{ijkl} = \mathbf{T}^{ijkl} \quad (18)$$

$$d\,\psi \cong \int \omega^0, \ \omega^0 \neq 0: \ (K^{\alpha\beta\gamma\chi} \neq 0, R_{\alpha\beta\gamma\chi} \neq 0) \quad (19)$$

$\psi = 0$

The line (11) in this scheme corresponds to the nonidentic initial evolutionary relation (with the exterior forms of degree 3). Here the inequality $d\omega^3 \neq 0$ is written in terms of the tensor expressions for the commutators: $(K_{\alpha\beta\gamma\chi} \neq 0, \ R_{\alpha\beta\gamma\chi} \neq 0)$.

The dotted line corresponds to the degenerate transform and to the transition from the nonidentic evolutionary relation to the identic relation on the pseudostructure of the dimension $m = 1$ (the line (12)), as well as to the nonidentic relation of one less degree (the line (13)). The line (12) contains the identic relation in the tensor expressions (see, the relation (6)), which corresponds to the identic relation (4) in the differential forms.

Under the degenerate transform it is once more allowed a transition from the nonidentic relation in the line (13) to the identic relation on the pseudostructure of the dimension $m = 2$ (the line (14)) and to the new nonidentic relation (the line (15)). Similar transitions can be realized under the degenerate transforms up to the closed inexact forms of zero degree. The solid line corresponds to the transition to the exact form.

A realization of the pseudostructures of dimensions $(1, ..., 4)$ and closed inexact forms of degrees $(3, ..., 0)$ (an origination of the physical structures $\mathbf{S}^i_{jkl}, ..., \mathbf{S}^{ijkl}$) correspond to formation of the pseudometric manifold. A transition to the exact form corresponds to a transition to the metric space.

And what can one say concerning the pseudoriemann manifold and the Riemann space?

As it is known, when deriving the Einstein equation [28] it was supposed that the following conditions to be satisfied: the Bianchi identity is fulfilled, the connectivity coefficients are symmetric ones (the connectivity coefficients are the Christoffel symbols), and there is a transformation under which the connectivity coefficient becomes zero. These conditions are those of realization of the degenerate transforms for the nonidentical evolutionary relations (13), (15), (17), (19). If the Bianchi identities are satisfied [20], then from the tensor expression $R^\alpha_{\beta\gamma\chi}$ the Riemann-Christoffel tensor G^i_{jkl} can be obtained. To the tensor expression $R^{\alpha\beta}_{\gamma\chi}$ there corresponds the commutator of the first order metric form $(\Gamma^\rho_{\mu\nu} - \Gamma^\rho_{\nu\mu})$, from which under the conditions of symmetry of the connectivity coefficients $(\Gamma^j_{lk} - \Gamma^j_{kl}) = 0$ the Ricci tensor can be found. To the tensor expression $R^{\alpha\beta\gamma}_\chi$ there corresponds the connectivity $\Gamma^\rho_{\mu\nu}$, from which under the condition $\Gamma^j_{kl} = \{ {j \atop kl} \}$ (the connectivity coefficients are equal to the Christoffel symbols) it can be obtained the tensor expression $\mathbf{S}^{ijk}_l$, which corresponds to the Einstein tensor $S^k_l = G^k_l - \frac{1}{2}\delta^k_l G$ (the tensors G^k_l and G are obtained from the Riemann-Christoffel tensor with taking into account the symmetry of the connectivity coefficients). To Einstein's equation there corresponds the identity (16) that connects the tensor expression $\mathbf{S}^{ijk}_l$ with the tensor expression $\mathbf{T}^{ijk}_l$ which corresponds to the energy-momentum tensor. (It is well to bear in mind that the metric tensor has not formatted as yet, and therefore the operation of transfer of low and top subscripts with the help of the metric tensor proves to be inapplicable). To the tensor expression $R^{\alpha\beta\gamma\chi}$ there corresponds the connectivity coefficients, which under a presence of the degenerated transform vanish, and this corresponds to a formation of the closed (inexact) metric form of zero degree $g_{kl} = (\mathbf{e}_k \mathbf{e}_l)$. However, at given stage this only corresponds to formation of the pseudoriemann manifold. A transition from the closed inexact form of zero degree to the exact form of zero degree corresponds to transition to the Riemann space.

Appendix 7

Functional properties of solutions to the differential equations. The field equation. Transformations

While description of the physical processes by differential equation the following fact is essential. As to the exact conservation laws there have to correspond the closed forms, then to them may correspond only solutions, whose derivatives constitute the closed form, i.e. a differential. What conditions must the differential equations satisfy to, for to have such solutions? Let us trace this by the example of the first order partial differential equation:

$$F(x^i,\, u,\, p_i) = 0, \quad p_i = \partial u/\partial x^i. \tag{1}$$

Let us consider the functional relation

$$du = \Theta, \tag{2}$$

where $\Theta = p_i\, dx^i$. This relation is an analog to the evolutionary relation, and in the general case this relation (as well as the evolutionary relation) proves to be nonidentical. For this relation to be identical one, the both parts of the relation have to be differentials, i.e. the closed forms. To obey this condition, the commutator $K_{ij} = \partial p_j/\partial x^i - \partial p_i/\partial x^j$ of the form $\Theta = p_i dx^i$ has to be zero. However, from the equation (1) it does not evidently follow, that the derivatives $p_i = \partial u/\partial x^i$, which obey to the equation (and given boundary or initial conditions of the problem), are conjugate, that is, they made a commutator of the form Θ equal to zero. In the general case without any supplementary conditions a commutator of the form Θ is nonzero.The form $\Theta = p_i\, dx^i$ proves to be nonclosed and is not a differential unlike the left-hand side of the relation (2). The functional relation (without supplementary conditions) proves to be nonidentical. And as the derivatives of the initial equation do not format a differential, then the corresponding solution to the differential equation u will not be a function of x^i. It will depend on the commutator of the form Θ, that is, it will be a functional.

To obtain the solution, which is the function, it is necessary to add a closure condition for the form $\Theta = p_i dx^i$ and for the form dual to that (in the present case the functional F plays a role of the form dual to Θ) [13]:

$$\begin{cases} dF(x^i,\, u,\, p_i) = 0 \\ d(p_i\, dx^i) = 0 \end{cases}. \tag{3}$$

If expand the differentials, then we get a set of the homogeneous equations with respect to dx^i and dp_i (in space of the dimension $2n$ – initial and tangential):

$$\begin{cases} \left(\frac{\partial F}{\partial x^i} + \frac{\partial F}{\partial u} p_i\right) dx^i + \frac{\partial F}{\partial p_i}\, dp_i = 0 \\ dp_i\, dx^i - dx^i\, dp_i = 0 \end{cases}. \tag{4}$$

The solvability conditions for this set (a vanishing of the determinant composed of the coefficients at dx^i, dp_i) have the form:

$$\frac{dx^i}{\partial F/\partial p_i} = \frac{-dp_i}{\partial F/\partial x^i + p_i \partial F/\partial u}. \tag{5}$$

These conditions determine an integrating direction, namely, a pseudostructure, on which the form $\Theta = p_i\, dx^i$ turns out to be closed one, i.e. it becomes a differential, and the relation (2) proves to be identity. If the conditions (5), which may be called the integrability conditions, are fulfilled, the derivatives constitute a differential ($\delta u = p_i dx^i = du$) and the solution becomes the function. Just such solutions (functions on the pseudostructures) are so-called generalizated solutions [29]. {As the functions, which are the generalizated solutions (distributions), are defined only on the pseudostructures, then they have breaks of derivatives in directions being transverse to the pseudostructures. The order of derivatives, which have breaks, is equal to a degree of the exterior form. If the form of zero degree enters into the functional relation, then the function itself will have the breaks}.

If to find the characteristics of the equation, then it appears that the conditions (5) are the equations for characteristics [30]. The characteristics are the pseudostructures, on which the solutions prove to be functions (generalized solutions). {The coordinates of the equations for characteristics are not identical to the independent coordinates in the initial equation (1). A transition from coordinates of the initial space to the characteristic manifold appears to be the **degenerate** transform, namely, the determinant of the set of equations (4) becomes zero. The derivatives of the equation (1) transfer from the tangent space to cotangent one}.

A partial differential equation of the first order has been analyzed, and the functional relation with the form of the first degree has been considered. (At this point it worth noting that for this equation one has to write down and analyze the additional relation with the zero-order form as well). Similar functional properties have the solutions to all differential equations. And, if the order of the differential equation is k, then to this equation there corresponds $(k+1)$ functional relations, every of which contains the exterior forms of degrees: $k,\, k-1, ..., 0$. In a similar manner one can investigate the solutions to a set of the differential equations and the ordinary differential equations (for which the nonconjugativity of the unknown functions and initial conditions are examined). {As it is known, the analyses of the unstable solutions and the integrability conditions provides the basis of the qualitative theory of the differential equations. From the functional relation it follows that to the instability it leads a dependence of the solution on the commutator, and as the integrability condition it serves the closure conditions of the form

composed of derivatives. It is evident that an analyses of the nonidentical functional relation lies at the basis of the qualitative theory of the differential equations}.

The functional properties of the differential equation play an essential role under description of the physical processes. It is clear, that to the conservation laws, and hence, to the physical structures, there can correspond only generalized solutions, whose derivatives format the closed form. The solutions-functionals have a physical sense as well. The solutions to the equations of the balance conservation laws, which are functionals, describe nonequilibrum states of the material system. And a transition (under the degenerate transformation) from the solution-functional to the generalized solution (a transition from the nonintegrable form to the closed one) corresponds to origin of the physical structure.

Because of that to the physical structures, which format the physical fields, there correspond the closed forms, then only the equations with the additional conditions (integrability conditions) can be the equations of field theory.

Let us return to the equation (1). Suppose, that it does not explicitly depend on u and it is solved with respect to some variable, for example t, that is, it has the form

$$\frac{\partial u}{\partial t} + E(t, x^j, p_j) = 0, \quad p_j = \frac{\partial u}{\partial x^j}. \tag{6}$$

Then the integrability conditions (5) take the form (in this case $\partial F/\partial p_1 = 1$)

$$\frac{dx^j}{dt} = \frac{\partial E}{\partial p_j}, \quad \frac{dp_j}{dt} = -\frac{\partial E}{\partial x^j}. \tag{7}$$

The conditions (7) are known as the canonical relations. (It can be seen that the canonical relations are the equations for characteristics of the equation (6)). The equation (6) provided with the supplementary conditions, namely, the canonical relations (7), is called the Hamilton-Jacobi equation [30]. The derivatives of this equation format the differential: $\delta u = (\partial u/\partial t)\, dt + p_j\, dx^j = -E\, dt + p_j\, dx^j = du$. To this type there belongs the equation of field theory

$$\frac{\partial s}{\partial t} + H\left(t, q_j, \frac{\partial s}{\partial q_j}\right) = 0, \quad \frac{\partial s}{\partial q_j} = p_j, \tag{8}$$

where s is the field function for the action functional $S = \int L\, dt$. Here L is the Lagrange function, H is the Hamilton function: $H(t, q_j, p_j) = p_j\, \dot{q}_j - L$, $p_j = \partial L/\partial \dot{q}_j$. To the equation (8) there correspond the closed form $ds = H\, dt + p_j\, dq_j$ (the Poincare invariant). { In the quantum theory an analog to the equation (8) is the Schrödinger equation [31]}.

{Here the degenerate transformation is a transition from the Lagrange function to the Hamilton function. An equation for the Lagrange function, that is the Euler variational equation, has been obtained from the condition $\delta S = 0$, where S is the action functional. In the real case, when forces are nonpotential or connections are nonholonomic, the quantity δS is not a closed form, that is, $d\,\delta S \neq 0$. But the Hamilton function is obtained from the condition $d\,\delta S = 0$ which is the closure condition for the form δS. A transition from the Lagrange function L to the Hamilton function H (a transition from variables q_j, $\dot{q}_j$ to variables q_j, $p_j = \partial L/\partial \dot{q}_j$) is a transition from the tangent space, where the form is nonclosed, to cotangent space with closed form. One can see, that this transition is degenerate one}. {In the invariant field theories there used only nondegenerate transformations, which preserve the differential. By the example of the canonical relations it is possible to show that nondegenerate and degenerate transformations are connected. The canonical relations in the invariant field theory correspond to nondegenerate tangent transformations. At the same time, the canonical relations for the Hamilton-Jacobi equation without supplementary conditions are the equations for characteristics, which the degenerate transformations correspond to. The degenerate transformation is a transition from the tangent space $(q_j, \dot{q}_j))$ to the cotangent (characteristic) manifold (q_j, p_j). It is a transition from manifold that corresponds to the material system, to the physical fields, and it is an origin of the physical structure. On the other hand, the nondegenerate transformation is a transition from one characteristic manifold (q_j, p_j) to the other characteristic manifold (Q_j, P_j), that is, a transition from one physical structure to another physical structure. It is easily shown that it is a specific feature for the relations, which perform such transformations as tangent, gradient, contact, gauge, conformal mapping, and others}.

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FIELD FORMULATION OF THE GENERAL RELATIVITY AND PROBLEMS OF COSMOLOGY

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It is shown, that the Einstein equations with the cosmological term describe only the flat and static Universe. They are conversed to the field shape and are simplified under these requirements. The solution of these equations is found in the shape of the Yukawa potential, which contains the constant called as the gravitational interactions radius. The concept of a gravitational interactions area of a material body with the Universe is defined according to the constant. It is shown, that the given area changes its location in the space at acceleration or retarding of the body action. It is accompanied by energy change of the body gravitational connections with the Universe. The identity of inertial and gravitational masses is proved unambiguous at definition of the character and quantity of these changes according to the Mach principle.

1. Introduction

Cosmology is the general part of mathematics, physics, astronomy and philosophy, which deals with origin, structure and development of the Universe as a whole. It is a unified concept of the Universe that puts cosmology in a position specific towards other sciences.

Really, if any other science can investigate its object from different directions and in full, only a part of the Universe is accessible to cosmology, i. e. a part of its object of investigation (to say the more, only from inside, as a cognising subject is inseparable from the object of investigation). As the whole possesses such properties which are not characteristic for its part, — and these are the properties which as a matter of fact distinguish the whole from its parts, then it makes clear enough the availability of all these drawbacks, which cosmology always experienced.

The essence of these drawbacks has always come to the one: no physical theory could to a full extent explain the observed properties of the Universe. If the theory somehow was adapted to some properties of the Universe, then the stemming effects either did not correlate with its other known properties or overstepped the limits of common sense. The situation is getting worse through the fact that four-dimension space-time by the General Relativity (GR) is described by ten variables, as the theory itself only suggests six independent equations. That is why it is not that surprising that nobody has ever managed to build the objective picture of the world only with the GR equations.

To study the whole by its part, it is important to have continuous integration of notions on the subject of the investigation from different points of view at every stage of its investigation and continuous coordination of outcomes of the theory under development with the objective reality. Non-observance of the principle of conformity, occurrence of internal contradictions, singularities and paradoxes while applying the given theory for the description of the whole indicates to the falsity of the way taken by the investigators. It is the very situation, which has developed in cosmology nowadays, its official theoretic ground being based on the idea of Big Bang.

2. Geometry of the conservation laws

Ten conservation laws tested with a high degree of accuracy are combined in a special way with the spacetime geometry.

This relates to the fact that in an arbitrary Riemannian spacetime the availability of a differential covariant conservation equation does not guarantee the possibility of deriving an applicable integrated conservation law. This feature allows us to work out of requirements to the geometry of four-dimensional spacetime, which, if met, would unequivocally produce the covariant integral conservation law.

Thus, the Killing equations have solutions, containing the greatest possible number $M = N(N+1)/2$ of arbitrary constants (parameters), if and only if the Riemannian space represents a space of constant curvature. If it does not represent the space of constant

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curvature, the will be fewer arbitrary parameters.

From the mathematical point of view, the availability of the integrated conservation laws of energy-momentum and the moment of motion reflects certain properties of spacetime: homogeneity and isotropy. There are only three species of four-dimensional spaces, which possess the properties of homogeneity and isotropy to such an extent that they allow the introduction of ten motion integrals for a finite system:

- space of constant negative curvature (the Lobachevsky space);
- space of zero curvature (the pseudo Euclidean space);
- space of constant positive curvature (the Riemannian space).

The first two spaces are infinite and have boundless volumes. The third space is closed having a finite volume, but no boundaries.

Simple supplementary studies [3] demonstrate that the pseudo Euclidean spacetime is in fact homogeneous and isotropic and, most importantly, it is only in this spacetime separate conservation laws of energy-momentum and moment of momentum take place for a finite system. Since natural geometry of the Universe is Euclidean at the global level, it is more expedient to treat the gravitational interaction just against a flat background.

3. The Special Relativity as a particular case of the General Relativity

To consider the problem in question, the interval of four-dimensional spacetime, filled with a substance, can be represented as:

$$dS^2 = g_{ab}dX^a dX^b + 2g_{0a}dX^0 dX^a + g_{00}\left(dX^0\right)^2, \quad (1)$$

where the indices a and b run values 1, 2, 3.

4. The following equality holds for the proper time

$$dX^1 = dX^2 = dX^3 = 0, \quad (2)$$

and the interval of the proper time is expressed by the relation

$$dt = \frac{1}{c}\sqrt{g_{00}}dX^0. \quad (3)$$

In the static case, all the components of $g_{0\alpha}$ of the metric tensor are identically equal to zero, but the spatial interval is defined as

$$dl^2 = -g_{ab}dX^a dX^b. \quad (4)$$

If a material particle leaves from point A at a moment X^0 of the world time and comes to the infinitesimally close point B at a moment $X^0 + dX^0$, then to define the velocity, it is necessary to take not the interim $\left(X^0 + dX^0\right) - X^0 = dX^0$, but the difference between $X^0 + dX^0$ and the moment $X^0 - \left(g_{0\alpha}/g_{00}\right)dX^\alpha$ that is simultaneous at the point B to the moment X^0 at the point A:

$$\left(X^0 + dX^0\right) - \left(X^0 - \frac{g_{0a}}{g_{00}}dX^a\right) = dX^0 + \frac{g_{0a}}{g_{00}}dX^a. \quad (5)$$

If we multiply it by $\sqrt{g_{00}}/c$, we will obtain the corresponding interval of the proper time, so that the velocity is defined as

$$v^a = \frac{cdX^a}{\sqrt{g_{00}}\left(dX^0 + \frac{g_{0a}}{g_{00}}dX^a\right)}. \quad (6)$$

In the static case, expression (6) is simplified to the form

$$v^a = \frac{cdX^a}{\sqrt{g_{00}}dX^0}. \quad (7)$$

On the other hand,

$$v_a = -g_{ab}v^b. \quad (8)$$

Then

$$v^2 = v_a v^a = -g_{ab}v^a v^b =$$

$$= -g_{ab}\frac{cdX^a}{\sqrt{g_{00}}dX^0}\cdot\frac{cdX^b}{\sqrt{g_{00}}dX^0} =$$

$$= -g_{ab}dX^a dX^b\frac{c^2}{g_{00}\left(dX^0\right)^2} = \frac{c^2 dl^2}{g_{00}\left(dX^0\right)^2}. \quad (9)$$

Now it is possible to write the expression for the square of the interval in the moving frame of reference

$$dS^2 = g_{00}\left(dX^0\right)^2 + g_{ab}dX^a dX^b =$$

$$= g_{00}\left(dX^0\right)^2 - dl^2 =$$

$$= g_{00}\left(dX^0\right)^2\left(1 - \frac{dl^2}{g_{00}\left(dX^0\right)^2}\right) =$$

$$= g_{00}\left(dX^0\right)^2\left(1 - \frac{1}{c^2}\frac{c^2 dl^2}{g_{00}\left(dX^0\right)^2}\right) =$$

$$= g_{00}\left(dX^0\right)^2\left(1 - \frac{v^2}{c^2}\right). \quad (10)$$

Since astronomical observations testify that the Universe at the global level is flat and for the flat spacetime, while applying the Lorentzian coordinates

$$g_{00} = 1, \quad (11)$$

one may reduce expression (10) to the form

$$dS^2 = \left(1 - \frac{v^2}{c^2}\right)\left(dX^0\right)^2 = g'_{00}\left(dX^0\right)^2, \tag{12}$$

where the value

$$g'_{00} = 1 - \frac{v^2}{c^2} \tag{13}$$

is the component of a new metric tensor (in the moving frame of references).

Then the interval of the proper time in the moving frame of reference will be defined as

$$d\tau = \sqrt{1 - \frac{v^2}{c^2}}\frac{dX^0}{c} = \sqrt{1 - \frac{v^2}{c^2}}dt, \tag{14}$$

which, for its part, is typical only for the special theory of relativity.

Therefore, special relativity represents a special case of the general theory of relativity only in the case of a flat, homogeneous, isotropic and static material medium. In other words, space and time have now become inseparable from substance both in special relativity and in general one.

As all the formulas of special relativity hold true with exceptional precision in the nature, it can be deduced that the entire Universe is static at the global level.

5. Expansion of metric tensor

The metric tensor of the four-dimensional spacetime g_{ik} in the case of a weak field is traditionally presented in the form of the sum

$$g^{ik} \approx \gamma^{ik} + h^{ik} = \widehat{g}^{\,ik}, \tag{15}$$

This expansion of the metric tensor is only approximate in all cases, as it does not correspond to the basic requirements presented to fundamental metric tensors of the Riemannian space.

In fact, the mixed components and full convolution of the tensor $\widehat{g}^{\,ik}$ have the form [1]:

$$\widehat{g}^{\,i}_{k} = \delta^i_k + h^i_k, \tag{16}$$

$$\widehat{g}_{ik}\widehat{g}^{\,ik} = 4 + 2h + 0\left(h^2_{ik}\right). \tag{17}$$

At the same time, for the truly metric tensor in the Riemannian space, the following precise relationships should always be executed:

$$g^i_k = \delta^i_k, \tag{18}$$

$$g_{ik}g^{ik} = 4. \tag{19}$$

Therefore, works [2, 3, 5–7, 9–11] have switched to the transition to the precise expansion of the metric tensor g_{ik} to two parts that correspond to consideration of the gravitational field of material objects against a certain background. In those theories, the switch from the transferring from the geometric formulation of gravity to the field formulation has been made by means of the precise (precise!) expression

$$\sqrt{-g}g^{ik} \equiv \sqrt{-\gamma}\left(\gamma^{ik} + h^{ik}\right), \tag{20}$$

A simple check demonstrates that the left-hand side of the given transformation conforms to requirements (18) and (19) if the parameters

$$\tilde{g}^{ik} = \sqrt{-g}g^{ik}, \;\; \tilde{g}_{ik} = \frac{1}{\sqrt{-g}}g_{ik}. \tag{21}$$

are introduced. Conformity of right-hand sides in transformations (20) to requirements (18) and (19) by means of correlations (21) is also evident.

After that we may proceed to determine the form of field equations of general relativity, but first needs to be selected of the equations themselves in a geometrical presentation.

6. Selection of Einstein's equations

As has already been mentioned above, there are two varieties of the Einstein's equations written in the geometrical form. Let us write them once more:

$$R_{ik} - \frac{1}{2}Rg_{ik} = -æT_{ik}, \tag{22}$$

$$R_{ik} - \frac{1}{2}Rg_{ik} - \lambda g_{ik} = -æT_{ik}, \tag{23}$$

From the collection of all the characteristics of the Universe, it is necessary to select that, which would allow us to make an unambiguous choice of the Einstein's equations. Such characteristic is the global Euclideation of the Universe. Since in this case $g_{ik} = conct$ and $g_{ik,l} \equiv 0$, then we arrive at equality

$$R^l_{ijk} = R_{ik} = R = 0. \tag{24}$$

Using the chosen criterion, we shall analyse the equations (22) and (23). For the beginning we form of them convolutions:

$$R = æT, \tag{25}$$

$$R + 4\lambda = æT. \tag{26}$$

For the real Universe, filled with substance, $T \neq 0$. Because æ is not equal to zero either, it becomes evident that equality (25) fails to hold if expression (24) has been accounted for. Therefore, equations (22), from which the said equality has been obtained are not true

either. On the contrary, equality (26) holds which in turn points to the fact that equations (23) can be applied to describe of the real Universe (though initially some principal difficulties concerning the superhard state of the substance of the Universe).

It should be noted that the inference given above also follows from equations (22) and (23). However, in this case equality (26) alos produces the expression for the cosmological constant

$$\lambda = \frac{1}{4}æT, \tag{27}$$

which plays a fundamental role in explaining the properties of the Universe if condition (24) has been met.

7. Principles of deriving field equations

The transfer from the geometrical formulation to the field one is made with the help of the correlation

$$\sqrt{-g}g^{ik} \equiv \sqrt{-\gamma}\left(\gamma^{ik} + h^{ik}\right), \tag{28}$$

This corresponds to the specified tensor gravitational field h^{ik} against the background of the flat material world in the arbitrary curvilinear coordinates with the metric γ^{ik}.

In the flat world, the Lorentzian frame of reference can be selected and then the linear member acquires the form

$$d\sigma^2 = \eta_{ik}dx^i dx^k = c^2dt^2 - dx^2 - dy^2 - dz^2. \tag{29}$$

However, to achieve greater generalization, we will so far use the arbitrary curvilinear coordinates with the metric tensor γ^{ik}. Allowance for homogeneity and isotropy of the Universe will be made by means of equalization to zero of the covariant derivative of tensor gravity $\tilde{g}^{ik}$ (which is true in all the frames of reference)

$$\left(\sqrt{-g}g^{ik}\right)_{;k} = 0, \tag{30}$$

If identity (24) is allowed for, identity (30) is father transformed, in the Lorentzian coordinates, into a condition that coincides with the harmonicity condition [2]

$$\left(\sqrt{-g}h^{ik}\right)_{;k} = 0. \tag{31}$$

Conditions (30) and (31) resemble the Lorentz calibrating condition that holds in electrodynamics, but here the conditions are mandatory since they reflect quite particular properties of real spacetime of the Universe. (In electrodynamics, incidentally, these conditions are also obligatory!) After that, two principles of deriving field equations of general relativity arise.

The first principle is associated with direct transformations of equations (22) and (23) in equations of the field formulation of relativity by applying correlation (28). In this instance equations (22) acquire the form

$$h^{;\alpha}_{ik;\alpha} + \gamma_{ik}h^{\alpha\beta}_{;\alpha;\beta} - h^{\alpha}_{k;i;\alpha} - h^{\alpha}_{i;k;\alpha} = 2æT'_{ik}, \tag{32}$$

in which the designation

$$T'_{ik} = T_{ik} + T^g_{ik}, \tag{33}$$

is introduced, where T_{ik} is the energy-momentum tensor of all material sources apart from the gravitational field; T^g_{ik} is the energy-momentum tensor of the gravitational field. Taking into account the identity

$$h^{;\alpha}_{ik;\alpha} \equiv oh_{ik} \tag{34}$$

and condition (31), which at the inverse transformation with allowance for (30) and (28) becomes

$$h^{ik}_{;k} = 0, \tag{35}$$

we obtain

$$\Box h_{ik} = 2æT'_{ik}, \tag{36}$$

Equations (23) will change similarly and in the long run they turn into

$$\Box h_{ik} - \frac{2}{3}\lambda h_{ik} = 2æT'_{ik}. \tag{37}$$

The second principle first supposes the transformation of the Hilbert Lagrangian, which, for example, without regard for the cosmological constant, looks like

$$L = \sqrt{-g}R, \tag{38}$$

to the Lagrangian L^g of the field formulation of general relativity. After that, with the help of the variation principle and with account for (30), (31) or (35) the field equations of gravity, which are identical to equations (36), are obviously gained.

The second principle is more laborious to realize than the first one. However, it allows a deeper comparison of the two presentations of general relativity, touching not only the identity of equations, but also the identity of two Lagrangians, on the basis of which the equations of the given theory are derived.

As for the cosmological constant, it obviously depends on the properties of the material medium of the Universe (27). Because of that, the Lagrangian of the geometrical formulation of general relativity is chosen in the form

$$L_\lambda = \sqrt{-g}\left(R + 2\alpha\lambda\right), \tag{39}$$

where α is a certain constant (number) in dependent of any factors except for the fact that the field equations of general relativity correspond to the Newton gravitation law for weak fields and short distances. The variation principle applied to the Lagrangian (39), in view of the above reservation concerning α and condition (35), results in equations (37).

8. Law of universal gravitation. Large-scale structure of the Universe

In a static case for spherical-symmetric material body of m mass, equation (37) gives an external solution as a Yukawa potential

$$\varphi = -\frac{Gm}{r}\,\mathrm{e}^{-r/R_0}. \tag{40}$$

where the constant R_0 is called as a radius of gravitational interactions and is determined through mean density of the Universe ρ_0 and relative velocity of a light c' under the formula

$$R_0 = c'\sqrt{\frac{3}{4\pi G\rho_0}}\quad, \tag{41}$$

For two material objects with m_1 and m_2 masses the following law of gravitation is received

$$F = G\frac{m_1 m_2}{r^2}\,\mathrm{e}^{-r/R_0}\left(1+\frac{r}{R_0}\right). \tag{42}$$

From the analysis of the obtained law it follows that all material bodies (planets, stars, galaxies) in the Universe interact less, than it stems from Newton's gravitation law. The latter, in its turn, arises from the actual law of gravitation with average density of the Universe tending to zero. Here lies the principle of conformity with reference to the given law and explanation how material environment of the Universe influences interaction of components by this.

In linear approximation the law of universal gravitation takes the following shape

$$F = G\frac{m_1 m_2}{r^2}\left(1-\frac{r^2}{R_0^2}\right), \tag{43}$$

which shows that all material bodies in the Universe only interact practically within the radius of gravitational interactions equal to approximately 10^{-26} m (or 20 billions of light years).

The actual law of gravitation has a number of nice characteristic properties. Thus, the evaluation of energy connection of material body of m mass with the whole Universe gives the value

$$E = -mc^2, \tag{44}$$

which is exactly equal to inner energy of the body taken with the opposite sign. Unlike this, Newton's law of gravitation gives minus infinity. That is why, application of Newton's law gave birth to Zeeliger's paradox. In the actual Universe there is no such paradox as to the actual law of gravitation, and mass serves as a measure of connection of this material body with the Universe.

In classical physics there is a special theorem, proving that in spherical-symmetrical material envelope the gravitational field is absent or, to be more exact, that the resultant of all gravitational forces is equal to zero. With the use of actual law of gravitation it turned out that such envelope (with mass M) attracts material point of m mass, situated in the internal cavity, with the force

$$F = \frac{GmM}{r^2}\frac{R_0}{2R}\times$$
$$\times\left[\mathrm{e}^{-\frac{R+r}{R_0}}\left(1+\frac{r}{R_0}\right) - \mathrm{e}^{-\frac{R-r}{R_0}}\left(1-\frac{r}{R_0}\right)\right]. \tag{45}$$

Analysis of the formula (45) shows, that the closer the point to the envelope (r is the closest distance between the point and the envelope), the stronger it is attracted. In other words, any stabilisation of material media of the Universe in the shape of the envelope leads to the further forming of such an envelope. That is why the Universe in large scales has got cellular structure (in the shape of soap foam), where the conglomerations of the galaxies are in the thin walls of these cells, and superconglomerations are at the crossings of the cells.

As for the global structure of the Universe, the author has proved the special theorem, showing that formulas of the Special Theory of Relativity (STR) are only true for flat and static Universe. Moreover, STR is shown to be a particular case of the GR, and space and time in it, as well as in the GR, are inseparable from substance.

9. Laws of dynamics. Gravitational viscosity. Geodetic curvature of the Universe

Complicated enough (demanding substantial imagination) analysis of interaction of a material body with all the masses of the Universe on its speeding-up showed that the character of this interaction is changing in the intricate manner: the interaction of the speeding-up body with the Universe is decreasing in the back hemisphere and, on the contrary, is increasing in the front one.

In more simple way, it can be explained using linear approximation of the actual law of gravitation (43). According to this approximation, a material body only interacts with the media of the Universe within the radius of gravitational interactions. When the body speeds up, the field of interaction without shape changing moves ahead in its run in proportion as the velocity of the body to the velocity of light.

The author has worked out the method to determine quantitative characteristics of the dynamics of this interaction and to show, that the second Newton's law

is a consequence of this interaction. At this, the second Newton's law automatically includes gravitational mass instead of inert one, traditionally accepted. Thus, the author has proved the identity of inert and gravitational masses in the spirit of Mach principle. In other words, no inert mass is proved to exist, and inert properties of material bodies come out through gravitational interactions with all the masses of the Universe (more exactly, through changing this interaction). Centrifugal forces at rotation, reflecting the third law of Newton, are explained in the same way.

After speeding-up (cessation of local force functioning) of a material body along the X coordinate, its free movement is described with the equation:

$$\frac{d^2X}{dt^2} + H\frac{dX}{dt} = 0, \tag{46}$$

where H is Hubble's constant, which is determined by the formula

$$H = \sqrt{\frac{4\pi G\rho_0}{3}}, \tag{47}$$

and has another physical sense, than it is accepted in cosmology.

The new law of free movement differs from the first Newton's law by the presence of the second (dissipation) addend. Altogether, one of the simple wording of this law may be the following: if a body is not affected by local forces, then the position of its field of interaction with the Universe (by R_0 level) in due course of time will not change, and it itself aims asymptotically at the centre of this field.

As the decrease of object velocity is proportional to the velocity, and not to its quadrate, as it is observed in aerodynamics, such property is named gravitational viscosity of the Universe (by analogy with viscosity of any other environment). Due to the fact that the value of Hubble's constant has order 10^{-18}, the presence of gravitational viscosity practically has no effect at local processes (for example, within the Solar system). But at the distance equal to the half of the average distance between galaxies, the forces of gravitational viscosity become comparable with centrifugal forces and are responsible for formation of medium-scale structure of the Universe, i.e. for formation of galaxies (these forces also explain their spiralling).

The concept of gravitational viscosity of the Universe closely links to the concepts of affinities (parallel carry of vector) in the non-Euclidean geometry of multidimensional spaces. For movement of non-conservative systems, i. e. in most general view, there is a relation:

$$K^j(t) = \frac{d^2X^j}{dt^2} + \Gamma^j_{lk}\frac{dX^l}{dt}\frac{dX^k}{dt} = \varphi(t)\frac{dX^j}{dt}. \tag{48}$$

The average addend with Christoffel's symbols of the first kind (affine connectedness) Γ^j_{lk} indicates to the degree of space curvature (let's call it geometrical), where the parallel carry of vector is made, and the latter indicates to the change of the length of the very vector, i. e. to the existence of the energy dissipation. It defines the so-called geodetic curvature of space:

$$K = \sqrt{g_{ij}K^i(t)K^j(t)}, \tag{49}$$

which is practically not mentioned even in specialised literature on GR.

For the actual Universe the geodetic curvature is equal:

$$K = K_0\sqrt{1 - \frac{v^2}{c^2}}, \tag{50}$$

where $K_0 = Hc$ is a constant for Universe equal to approximately 10^{-10} m/s^2.

The interesting physical sense has also radius of gravitational interactions (41). It appears that it corresponds in precision to radius of a black hole on which surface the speed of light is equal to the first solar escape velocity. Thus, it is possible to tell that we live at in the centre of a black hole, but it is not our privilege, and the property of the Universe to form around of any point gravitational-makes area. By the way acceleration due to gravity on a surface of such black hole is equal only 10^{-10} m/s^2.

In general the analysis of all results demonstrates that the motion in respect to the Universe has the character of absolute motion, but it is impossible to observe it under local physical laws.

The actual law of gravitation gives one more important corollary: with mass shown in interactions with a material body depends on a relation of radius of a body R to radius of gravitational interactions R_0

$$M = \frac{R^2c^2}{2GR_0}\left(1 - \mathrm{e}^{-2R/R_0}\right). \tag{51}$$

At $R << R_0$ the mass of a body is proportional to its volume, and at $R >> R_0$ (or that is the same when $R \to +\infty$) to surface area of a body. It gives in a deduction about ability of a substance to create screen effect. It is capable to explain virial paradox and existence of gravitational-makes of areas of the Universe.

10. Law of light distribution. Hubble's diagram. Sky temperature

The analysis of interaction of light with material environment of the Universe showed that the distributed photon is affected by gravitational potential $(-c^2)$, resulting in its energy loss and in the result in changing light frequency ν in relation to original ν_0 by the law [8, 10]:

$$\nu = \nu_0\,\mathrm{e}^{-r/R_0}. \tag{52}$$

The given law fully solves photometry paradox, explains the nature of red shift in radiation spectra of other galaxies without using Doppler's effect and leads to a new formula of distance definition to galaxies:

$$L = R_0 \ln(1+z)\,, \tag{53}$$

where $z = (\lambda - \lambda_0)/\lambda_0$ is a parameter of red shift of light frequency, expressed through wavelengths of radiated λ_0 and λ light being received.

It is necessary to note, that in 1971 Carlsson [4] has found out for the first time a cyclic change of a spectral radiant density of quasars proportional argument $\ln(1+z)$, where z is red bias of their spectrums. Such allocation of quasars correlates with allocation of galaxies forming in the Universe homogeneous thin-walled aggregations as meshes.

In view of the formula (53) cyclic changes of a spectral radiant density of quasars are conversed to cyclic dependence of allocation of quasars on distances indicating homogeneity of the Universe not only in space, but also in time, that is on its stationarity for the last a minimum of 30 billions years (so much time the electromagnetic waves went to us from the farthest quasars).

Taking into account the new law of light distribution the dependence "visible stellar magnitude m — redshift z" (Hubble's diagram) takes the shape:

$$m = 5\lg\left[\sqrt{1+z}\ln(1+z)\right] + 21.68 \tag{54}$$

and fully coincides with experimental data, at this within the range of observed values for stellar magnitudes the given dependence is practically linear.

Law (52) fully explains the nature, numerical characteristics and the character of distribution of background microwave radiation. Actually it is not a relic of the Big Bang, but a summary radiation of all sources of electromagnetic radiation (stars, galaxies, etc.) of the Universe. If all radiation dropping on the single site is integrated in the space from the zero ad infinitum, the temperature of this radiation (sky temperature) will be determined by the formula:

$$T_0 = \sqrt[4]{\frac{L_S \Theta \rho_0 R_0}{4\sigma M_S}}. \tag{55}$$

where M_s, L_s is average mass and full flux of the radiation of an average star; σ is Stefan-Boltzmann constant, Θ is a share of stars in medial density of the Universe ρ_0.

It is known, that the medial mass of a star is equal approximately 0.4 masses of the Sun. Then, if in the formula (14) to substitute values of this mass $M_S = 0.8 \cdot 10^{30}$ kg and brightness, relevant to it $L_S = 1.1 \cdot 10^{25}$ W, and also constant $\sigma = 5.67 \cdot 10^{-8}$ $\mathrm{Wm^{-2}K^{-4}}$ and the value of density $\rho \approx 10^{-26}$ $\mathrm{kg/m^3}$ (i. e. that $\rho_0 R_0 \approx 1$), so for this performance $\Theta = 0.8 \div 1.0$ temperature of equilibrium radiation of all stars will be equal $T_0 = 2.64 \div 2.79$ K, that coinsides with actual measurings of this value (2.726 ± 0.005 K).

Other investigations have shown that the spectrum of integral sky radiation corresponds to the spectrum of absolutely black body radiation. And as the actual law of light distribution does not save as constant the light frequency, the following additions are introduced into the equation of electrodynamics.

11. Conclusion

Thus, the author has designed the new stationary model of the Universe which approximately on 30 parameters is compounded with the properties of the actual Universe and has the same right on existence as well as model of Big Bang.

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POLARIZATIONS WAVES AND PROBLEM OF GRAVITATION

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Gravitation is one of manifestations of body's reciprocal influence through ether. The mechanism of a gravitation consists of a constant reciprocal irradiation of bodies by polarization waves (P-waves), which excite forces of the attraction of irradiated bodies by ether in the direction of their interaction. The mechanism of the excitation has code character: the stimulating and provoked forces are opposite on a direction (P-waves are not a "pushing", but a "drawing" ones in difference from electromagnetic and sound waves), and by value the raised forces of an attraction are larger than stimulating them P-waves forces. The energy of gravitation is a converted energy of ether. Before P-waves discovery [1-4] a nature and mechanism of gravitation could not be discovered on principle. A nature of gravitational interactions, as well as all other fundamental interactions (strong, electromagnetic and slight), is mechanical

1. Introduction

The question of the nature of gravitation remained actual, but unsolved, within 300 years from the moment of Newton's discovery of the Universal Gravitation Law. Newton himself answered this question, that he does not know, and he does not want to dream ("I do not fabricate the hypotheses").

The problem is really so complicated, that for its solution the science needed for 300 years.

The opportunity of the decision of the problem depends on notions and level of knowledge about structure of substance, of universe.

Still Descartes has expressed the thesis, that the empty space is not present (17-th century, Cartesian school).

However, the dependence of gravitation force on medium between gravitating bodies did not enter as obvious one in the law of the universal gravitation, which has been discovered in that century

$$F_{\mathrm{Gr}} = G\frac{M_1 M_2}{R_{12}^2},$$

M_1, M_2 is mass of attracting (gravitating) bodies;
R_{12} is distance between them.

As it has been clarified now (see below (13.1)), this dependence enters a gravitational constant G the same way as the dependence on medium of force of interaction between two electric charges enters to the Coulomb's law through dielectric permittivity

$$F_{EL} = \frac{1}{4\pi\varepsilon}\frac{Q_1 Q_2}{R_{12}^2}.$$

Q_1, Q_2 is charges of bodies;
R_{12} is distance between them.

But for this "ascertaining" 300 years were required, as it was marked above. And the history of this ascertaining is next.

2. Historical-conceptual situation

2.1. As the gravitation force dependence on medium between gravitating bodies does not enter as obvious one in the Universal gravitation law, as it was marked above, it was thought,that it simply does not exist, and gravitation force propagates instantly through empty space (the conception of "long range actions").

The importance of the Universal gravitation law for science and engineering is so great, and the prestige of Newton was so high, that the conception of long range actions has being actual during 150 years up to Faraday's experiences.

2.2. Faraday by experiments with electrical and magnetic bodies has found out, that these bodies interact through special mediums, which he has termed electrical and magnetic fields, accordingly (conception of "short range interactions"). Maxwell analytically has described the existence of electromagnetic waves and has obtained the equations of electromagnetic fields and

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waves (for free space):

$$\mathrm{rot}\mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}, \tag{2.1}$$

$$\mathrm{rot}\mathbf{H} = \varepsilon_0 \frac{\partial \mathbf{E}}{\partial t}. \tag{2.2}$$

The materiality of ether and its very important property — electrical polarizability — appeared from Maxwell equations [1]. Really, from (2.2) it follows, that

$$\mathrm{div}\left(\varepsilon_0 \frac{\partial \mathbf{E}}{\partial t}\right) = \frac{\partial}{\partial t}(\mathrm{div}\,\varepsilon_0 \mathbf{E}) = \frac{\partial \rho}{\partial t} = 0,$$

$\varepsilon_0 \mathbf{E} = \mathbf{P}_{Eth}$ is polarization of "free" space.

But only the material medium can be polarized. So, the experiences of Michelson-Morley on searching of ether were not necessary any more after Faraday and Maxwell works.

It enabled and indicated the direction of examination of fundamental properties and structure of ether.

2.3. But the history gave orders in its own way. The Newtonian situation has repeated. Theoreticians with difficulties recognized Faraday-Maxwell laws. The search of ether was held in parallel. Positive results, as well as negative ones, were gained. Without a due justification the negative results of Michelson-Morley experiments have been recognized — ether does not exist.

For the explanation of these negative results Fitzgerald and Lorentz have put out the hypothesis of cutting of the sizes of bodies in a direction of their motion, then Lorentz has put out the additional hypothesis of time slowing-down in mobile objects. Lorentz has formulated these hypotheses as the equations, which we know as Lorentz transformations:

$$x' = (x - vt)\left(1 - \frac{v^2}{c^2}\right)^{-\frac{1}{2}},$$

$$t' = \left(t - \frac{vx}{c^2}\right)\left(1 - \frac{v^2}{c^2}\right)^{-\frac{1}{2}}$$

2.4. Einstein had his own vision of the universe. In Lorentz transformation laws he saw the manifestation of properties of objective reality — space-time continuum. On this basis he has generated at first the Special Relativity, and then the General Relativity. Though this theory difficultly yields to comprehension by "sensible" sense, the scientific prestige of the Einstein was so great, that this theory has been put in a basis of natural sciences paradigm, and in a basis of development of the gravitation theory also.

The existence of a picked out (absolute) reference system — ether (as it was showed above) — disturbs Einstein principle of relativity and consequently will demand the processing of the theory of relativity.

However, though the general theory of relativity was termed also as the theory of gravitation, it could not explain neither nature, nor mechanism of gravitational forces. In other words, it was not possible to materialize Lorentz transformations.

To puzzle out a nature and mechanism of gravitational forces and to develop a fundamentals of the theory of a gravitation it is possible on the basis of the analysis of structure and properties of ether (its materiality and electrical polarizability, as it was scored above, with necessity follow directly from Maxwell equations) and on the base of the discovery of polarization waves (P-waves) [1-4].

3. Nature and mechanism of gravitation

3.1. In a summary descriptive form a nature and mechanism of gravitation (universe interattraction of bodies) can be submitted as follows.

As Maxwell equations corollary (see above), whole space, both "free" one, and the material formations (bodies), are filled by electrically polarized medium - ether.

The substation (ether), which possesses property of an electrical polarizability, can be represented by gas of neutral particles (amers), in which bigger by size electrically polarized particles (polars) had been inserted.

3.2. The polars can be represented by dipoles made of "stuck together" vortex toroids of this amer gas.

Such representation reflects the property of an electrical polarizability of an ether and it is compounded with the vortex toroids formation theory (they are, on Helmholtz, inconvertible structures).

The vortex toroids with contrarily ordered ring velocities are attracted to each other (and this is primary microscopic and basic display of fundamental interactions), forming polars. The polars, thus, also have property to be attracted to each other and are both electrical, and gravitational dipoles.

3.3. The dipoles of polars oscillate on natural frequencies under action of microwave background radiation (MBR) and of thermal motion of gas, perturbing environmental amer gas, — i.e. they radiate amer "sound" waves. These sound waves transmit energy to the next polars — the polarization waves (P-waves) are formed.

3.4. The polars are in a state of chaotic thermal motion. P-waves will increase forces of polars interattraction by spatial orientation of interaction.

By this the polars of "free" space and polars of bodies are interattracted, and so as the polars are bound to particles of bodies, the bodies and ether will be interattracted.

Individual "remote" from each other bodies are under symmetric exposure of environmental ether and so

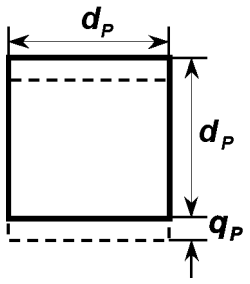

Figure 1: Polarized polar (Hertz dipole): d_P is diameter of vortical toroids of polar; q_P is dipole arm

the forces of attraction of bodies by ether will be balanced.

3.5. At an arrangement of bodies in relative proximity to each other the equilibrium is disturbed. The point is that though all polars radiate P-waves, but a density of polars in bodies is greater, than in "free" space, and, accordingly, an intensity of P-waves radiated by bodies will be larger. In addition, bodies reciprocally irradiate each other with P-waves. The attraction of bodies by ether from irradiated side is lager. Reciprocal gravitation (interattraction) of bodies appears.. Though, as a matter of fact, only forces between a body and ether operate. The interaction of bodies through P-waves only arouses these forces, determines their direction.

Let's mark also, that the interaction of P-waves has informational-code character: at first, P-waves are not a "pushing", but a "attracting" ones in difference from electromagnetic and sound waves; secondly, gravitational forces are larger then strength of P-waves influence. Converted energy of ether is a source of gravitational forces.

3.6. Thus, the nature of reciprocal gravitation forces, as well as their mechanism, is mechanical. All subsequent content of paper is devoted to a showing up, a proving (base on facts) and quantitative illustration of the expressed above thesis (gravitation — on the example of an attraction of the Earth by the Sun).

4. Parameters of ether particles

4.1. The main difficulty of an estimation of ether parameters consists in the following: as the existence of an ether as material mediums was not recognized by official science, there are extremely few works devoted to the examination of properties of ether. The known works are based on postulates about properties of space and time and have abstract character. Therefore, at our studies the corollaries following from the determined laws and data of experimental examinations were put in a basis of the estimation of parameters of ether [1-4]:

— electrical polarizability of ether following from Maxwell equations,

Table 1. Parameters of vacuum particles

	Polars	Amers
Mass $m_P m_A$, kg	10^{-88}	10^{-114*}
Diameter d_P,d_A, m	10^{-21}	$<<10^{-21}$
Quasi-electr. charge of a dipole Q_{PO}, C	10^{-33}	neutral
Number in unitary volume n_P,n_A, m^{-3}	10^{62}	10^{69*}
Resonance frequency ω_{P0}, rad/s	10^{48}	-

— abnormal magnetic moment of electron,

— phenomenon of polarization of vacuum (electron-positron pair birth),

— value of a "dark" substance density.

Polar is represented by a Hertz dipole (Fig. 1)

The obtained results are given in Tabl. 1.

* - Amers parameters are evaluated for the first time in this work (see p.6).

4.2. The parameters and properties of a polar as gravitational dipole are examined below.

5. Polarization waves (P-waves)

5.1. P-waves equation:

$$\left(\frac{\partial^2}{\partial z^2} - \frac{1}{v_E^2}\cdot\frac{\partial^2}{\partial t^2} - \mu_0^2\right)\cdot q_P\left(z,t\right) = 0,$$

$$v_E^2 = a_P^2\omega_{P0}^2 k_{\text{Coupl}}, \quad \mu_0^2 = 1/\left(a_P^2 k_{\text{Coupl}}\right),$$

a_P is mean distance between polars;

ω_{P0} is proper frequency of polar;

$k_{\text{Coupl}} \sim 1$ for plane waves.

The variance law:

$$\omega_K^2 = v_E^2\left(\mu_0^2 + k^2\right),$$

$$k = 2\pi m/\left(a_p N\right),$$

N is number of atoms in a chain.

5.2. Group propagation velocity of P-waves $v_P \sim 10^{28}$ m/s. Frequency $\omega_P \approx \omega_{P0} \approx 10^{48}$ rad/s.

The quantities v_P and ω_{P0} were improved during examination process, and that is reflected in [1-4].

5.3. P-waves radiated by living organisms and by inorganic bodies have been detected experimentally [5, 6]. Then again, we think that just P-waves were detected in works [7, 8] (authors of these works have not find a nature of radiation).

6. Densities and velocities of amer gas thermal motion

6.1. The experiments display, that living creatures (including the plants) "identify" each other and even at great distances. It means, that the frequency resolution of their systems of information transmission and reception satisfies the realization requirements of this ability of living creatures.

On the other hand, already there are weighty reasons to consider, that P-waves are the carriers of the "identification" information. These statements give basis for the prescribing (estimation) of a quality factor of polars.

6.2. By putting, that for the "identification" a bandwidth of order of the television one is necessary, $\Delta f_{Sp} = 10^7$ Hz, we will get, that, if there was number of canals $N_{Can} = 10^{20}$, a loaded Q-factor of polar dipole is:

$$D_P = \frac{f_{P0}}{\Delta f_{Sp}} \approx 10^{20}. \tag{6.1}$$

Then from

$$D_P = \frac{m_P v_{Pm}^2}{2} \Big/ \frac{M_A v_{Pm}^2}{2} = \frac{m_P}{M_A},$$

v_{Pm} is amplitude of velocity of toroids dipole oscillations in a polar;

M_A is amers mass, "pushed out" by a toroid at one oscillation, we get

$$M_A = m_P/D_P = 10^{-108} \text{ kg}. \tag{6.2}$$

Accordingly from $M_A \cong S_P d_P \rho_A$ amers gas density follows

$$\rho_A = \frac{M_A}{S_P d_P} \cong 10^{-45} \text{ kg} \cdot \text{m}^{-3}, \tag{6.3}$$

S_P is cross-section area of polar.

Amer mass

$$m_A = \rho_A / n_A = 10^{-114} \text{ kg}. \tag{6.4}$$

6.3 Then from $n_A k T_V = \rho_A \bar{v}_A^2/3$ it follows, that at

$$n_A = 10^7 n_P = 10^{69} \ m^{-3} \tag{6.5}$$

mean square velocity of amers thermal motion is

$$\bar{v}_A = (3 n_A k T_V/\rho_A)^{1/2} \cong 10^{45} \text{ m/s}. \tag{6.6}$$

T_V is thermal temperature of vacuum.

6.4 Mean time of amer transit between collisions

$$\tau_{Tr} \cong \mathrm{a}_A/\bar{v}_A \sim 10^{-67} \text{ s},$$

a_A is mean distance between amers.

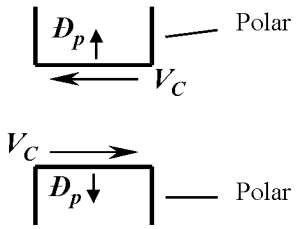

Figure 2: The mechanism of fundamental interaction between polars (V_C is circular velocity of amers movement in polar toroids)

6.5. Spectral density of energy of amer gas thermal motion

$$G_A^E = E_A/\Delta f_{Th} \cong E_A \tau_{Tr} = 10^{-21} J/Hz,$$

$$E_A = n_A k T_V.$$

6.6. Dispersion and mean square value of amers pressure on polar in its bandwidth

$$\sigma_P^2 = G_A^P \Delta f_{SP}, \quad G_A^P \sim G_A^W,$$

$$\sigma_P \cong 10^3 N \cdot m^{-2}. \tag{6.7}$$

7. Nature of fundamental interactions

7.1. Ultimately the reason of all fundamental forces and interactions is in the irregularity of a spatial distribution of density of matter and of velocity of its motion.

As to the division of these forces and interactions on strong, electromagnetic, slight and gravitational, it is stipulated by structure of the indicated irregularities only.

7.2. Between two layers of gas, moving with different velocities, a transport of a momentum and, accordingly, pressure differential appears at the expense of chaotic thermal transition of particles between layers.

By estimation of this differential for the case $v_{\text{Rapid}} >> v_{\text{Slow}}$ it is enough to take into account the transport of particles only to one side (to the side of a slow layer).

7.3. In this process the active space of gas layers interactions are only borders of stratums by width l_{Str} that will be equal to mean length of a transit between collisions l_{Tr}. In this part of a slow layer the pressure in the main will be determined by the particles which have obtained an acceleration at the expense of the thermalization of "rapid" particles, which come from a "rapid" stratum. In this part of a stratum the pressure will be

$$P \sim \rho \bar{v}_{\text{Rapid}}^{-2}/3,$$

ρ is gas density,

$\bar{v}_{\text{Rapid}}$ is mean thermal velocity of particles of the active stratum, which has obtained "rapidity" at the expense of indicated thermalization.

7.4. Be applied to a pressure between layers of amer gas in space of polars interaction (Fig. 2) it gives

$$P_P \sim \rho_A v_{\text{Rapid}}^2/3 >> \rho_A \bar{v}_A^2/3 = 10^{46} N \cdot m^{-2}, \quad (7.1)$$

$\rho_A = 10^{-45}$ kg $\cdot$ m^{-3} (see (6.3)),
$\bar{v}_A = 10^{55}$ m/s (see (6.6)).

This interaction between polar disks ends, which was caused by rotative moving of amer gas in vortical toroids in opposite directions, is "strong", and it is "torsion" — by structure.

So,

$$P_P = P_P^{\text{Str}}, \quad (7.2)$$

and $l_{\text{Str}} \sim l_{\text{Tr}}$ is strong interactions interval,

$$l_{\text{Str}} \sim n_A^{-1/3} = 10^{-23} \text{ m}, \quad (7.3)$$

($n_A = 10^{69}$ m^{-3}, see (6.5)).

7.5. In a steady-state regime this pressure will be counterpoised by pressure of next polar.

P-wave destroys the balance. The component of a pressure in the direction of a source of P-wave irradiation — gravitation pressure — appears

$$P_P^{\text{Gr}} \sim P_P^{\text{Str}} \frac{q_{Pm}}{\lambda_P} \cong 10^{38} N \cdot m^{-2}, \quad (7.4)$$

($q_{Pm} = 10^{-27}$ m, see (9.2)).

Energy of this interaction together with amers kinetic energy makes basis of fundamental interactions. With reference to strong and gravitational interactions it appears from following.

7.6. The pressure propagates with velocity $\sim v_A >> v_P$ from space of interaction of amer gas layers. Therefore relation (7.1) can be referred to all space between polars.

7.7. The pressure of quasielectric forces between polars

$$P_P^{El} = \frac{2}{\pi^2 \varepsilon_0} \frac{Q_{P0}^2}{a_P} \cong 10^{28} N \cdot m^{-2},$$

$a_P \sim d_P$. Hence, the electrical interactions are for many orders weaker then "strong" ones and even then gravitational forces.

8. Seed dipole moments of polars

8.1. At "free" space there is always MBR present. These fields electrically polarize polars. The polars, thus, have small (seed) electrical dipole moments.

8.2. Quantities of seed dipole moments of polars M_{PBg} can be evaluated by known density of MBR energy ($W_{\text{Bg}} \cong 4 \cdot 10^{-14} J \cdot m^{-3}$).

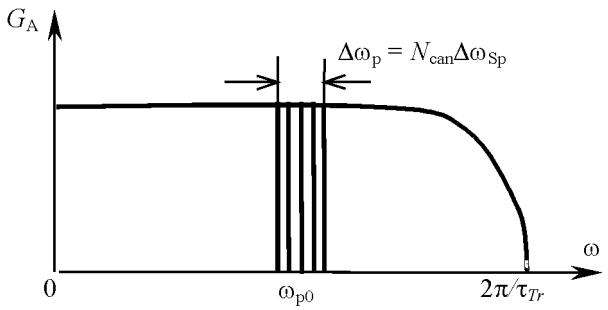

Figure 3: Energy spectrum of thermal motion of amer gas ($\Delta\omega_{Sp} = 2\pi\Delta f_{Sp}$)

From $\varepsilon_0 E_{\text{Bg}}^2 = W_{\text{Bg}}$ we get

$$E_{\text{Bg}} = 7 \cdot 10^{-2} V/m.$$

Then from $E_{\text{Bg}} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q_{P0}^2}{q_{\text{PBg}}^2}$ and $M_{\text{PBg}} = Q_{P0} q_{\text{PBg}}$ it follows that $M_{\text{PBg}} \cong 10^{-60} C \cdot m$.

8.3. The lengths of MBR are over the range from submillimetric wave up to decimetric wave. The oscillations of dipoles of polars, initiated by these fields, are low-frequency components. High-frequency components (on proper frequencies of polars) are superimposed on them.

9. Build-up of polars dipoles oscillations by amer gas thermal motion

9.1. From exposed above it follows, that polar on its properties is composite mechanic-electro-gravitational structural dipole formation. Being "seedily" polarized by MBR, it is in addition resonantly polarized (shaken) by thermal motion of amer gas.

9.2. Energy of amer gas thermal motion is distributed uniformly on frequency spectrum in the band. $0 \leq \omega \leq 2\pi/\tau_{Tr}$. Amer gas acts on polars by pressure spectral components, lying in a transmission band of a polar vibratory system $\Delta\omega_P$ (Fig. 3)

9.3. At a high quality factor of a polar vibrating system $D_P = \omega_{P0}/\Delta\omega_P >> 1$ the force acting on polars is narrow-band casual process and will be described by quasi-harmonic oscillations

$$F(t) = F_0(t) \cdot \cos[\omega_{P0} t + \varphi(t)],$$

$F(t)$, $\varphi(t)$ are slowly varying functions of time as compared with $T = 2\pi/\omega_{P0}$. $\sigma F_0 = \sigma_P S_P$,

σF_0 is mean-square value of force amplitude;

σ_P is mean-square value of spectral components of amer gas pressure situated in a transmission band of a vibrating system of a polar.

9.4. For an approximate estimation of a vibrations amplitude of a shoulder of polar's electrical dipole moment we shall consider the force active on polar as a harmonic function of time. Then the motion equation of a polar becomes:

$$m_P\ddot{q}_P + b\dot{q}_P - kq_P = F_0 \cos\omega_{P0}t, \tag{9.1}$$

$$b = m_P\omega_{P0}/D_P, \quad k = m_P\omega_{P0}^2,$$

D_P is loaded quality of a polar.

9.5. Solution of the equation (9.1) is the simple harmonic oscillation with amplitude

$$q_{Pm} = F_0 D_P / \left(m_P\omega_{P0}^2\right).$$

For the case under consideration at

$$F_0 = \sigma_P S_P = 10^{-41} N$$

$(\sigma_P = 10^{-3} N \cdot m^{-2}$; $S_P = \pi d_P^2/4$, see (6.7)),
$D_P = 10^{20}$ (see (6.1)), $m_P = 10^{-88}$ kg,
$\omega_{P0} = 10^{48}$ rad/s. We get

$$q_{Pm} = 10^{-27} \quad m. \tag{9.2}$$

Then the amplitude of the velocity of dipole oscillations of toroids in a polar is

$$v_{Pm} \sim q_{Pm}\omega_{P0} = 10^{21} \text{ m/s}. \tag{9.3}$$

9.6. Effective value of the pressure of amer gas "sound" waves radiated by polar

$$\tilde{P}_P^{\text{Sound}} = \rho_A \bar{v}_A v_{Pm} \cong 10^{22} N \cdot m^{-2}. \tag{9.4}$$

10. The influence of polars thermal motion on the intensity of "sound" waves in amer gas

10.1. Thermal motions of polars disorientate their dipole directions and so reduce the intensity of P-waves radiation of bodies and provoke the damping in their propagation in ether.

These effects can be accounted for by coefficients

$$K_{\text{Therm}}^B = \bar{F}_P^{\text{Rand}}/F_P^{\text{Or}}, \tag{10.1}$$

$\bar{F}_P^{\text{Rand}}$ is dipoles interaction force averaged by all reciprocal orientations (the energy of interaction $E_{\text{Int}} << kT$);

F_P^{Or} is force of interaction of two dipoles at their orientation "in tail" to each other.

10.2. Representing polar as equivalent electric dipole, we shall get

$$K_{\text{Therm}} \cong \frac{2}{3}\frac{Q_{Eq}^2}{kT}\frac{q_{Pm}^2}{a_P^3} \quad ,$$

$$Q_{Eq} = Q_{P0}\left(P_P^{\text{Gr}}/P_P^{El}\right)^{1/2} = 10^{-28}\ C.$$

10.3. Then for P-waves radiating by the Sun (Sun surface temperature $T_S = 6 \cdot 10^3$ K)

$$K_{\text{Therm}}^S \cong 10^{-28}. \tag{10.2}$$

Experience shows that P-waves attenuation in space is insignificant ($K_{\text{Therm}}^V \sim 1$). But this evaluation needs additional experimental verification.

11. Mutual irradiations of bodies by P-waves

11.1. By force of property of an electrical polarizability of ether, the polars, as it was noted above, have "seed" polarization initiated by relict EMF.

These dipoles are in addition polarized and spatially disoriented by blow-thermal motion of polars themselves and resonance-thermal motion of gas. In bodies, besides that, polars are polarized by intratomic EMF.

11.2. The load of these dipole oscillators is amer gas, in which they initiate "sound" oscillations of amer gas.

At random mutual dimensional orientation of radiating dipoles it is possible to consider, that the intensities of these radiated "sound" waves (of amer gas partial pressure) add vectorially. The effect of randomness can be accounted for by coefficients K_{Therm}^B and K_{Therm}^V (see p. 10).

11.3. Protons and electrons of bodies, having electric charges, attract polars. As a result the density of polars in bodies is lager than this in free space:

$$N_{PB} = n_P K_{\text{Fill}} V_B, \tag{11.1}$$

V_B is volume of body;

K_{Fill} is coefficient accounting the increasing of density of polars in the body in comparison with "free" space.

At $K_{\text{Fill}} \sim \rho_B$,
ρ_B is density of body, we get

$$N_{PB} = n_P M_B. \tag{11.2}$$

11.4. Partial sound pressure of amer gas of P-waves radiated by body 1 on polars of body 2 is

$$\tilde{P}_{12}^{\text{Sound}} = \frac{P_P^{\text{Sound}} S_P n_P K_{\text{Therm}}^{B_1} K_{\text{Therm}}^V M_1}{4\pi R_{12}^2}. \tag{11.3}$$

For the Earth irradiation by the Sun ($M_1 = M_S = 2 \cdot 10^{30}$ kg) we get

$$\tilde{P}_{ES}^{\text{Sound}} = 10^{21} N \cdot m^{-2}.$$

This pressure initiates gravitational attraction by code mechanism.

12. Code character of P-waves effect

12.1. "Sound" partial amer pressure of P-waves - is the repulsion, instead of the attraction of bodies (negative gravitation). But, at the same time, P-waves orient gravitational polar dipoles in a direction of their propagation and by that they will increase the force of their interattraction (gravitational) (the force of reciprocal gravitation).

As forces of interattraction are much greater than repulsive forces, then summary action of P-waves is attractive (P-waves, calling forces of intergravitation, are, thus, gravitational too).

12.2. The character of P-waves effect on bodies, thus, has code character. The coding property of this effect consists in the fact, that, at first, as it was marked above, P-waves are not "repulsive", but attractive ones, unlike electromagnetic waves; secondly, the force of reaction (the attraction) is much greater than the force of action (the repulsion). P-waves only excite attractive forces and for attraction itself the energy of amer gas thermal motion is used through dipole oscillations of polars.

Part of energy of progressive moving of polar dipole oscillations transforms to internal (torsion) energy of these toroids at the expense of difference of friction forces of its interior and external faces and, accordingly, to gravitation energy through "strong" interaction.

Quantitatively he coding property of polars gravitational effect is characterized by code coefficient

$$K^P_{\mathrm{Cod}} = \frac{\left|\tilde{P}^{\mathrm{Gr}}_P\right| - \left|P^{\mathrm{Sound}}_P\right|}{P^{\mathrm{Sound}}_P} \cong \left|\tilde{P}^{\mathrm{Gr}}_P\right| \Big/ \left|P^{\mathrm{Sound}}_P\right| \approx 10^{16},$$

$\left|\tilde{P}^{\mathrm{Gr}}_P = 10^{38} N \cdot m^{-2}\right|$ is the pressure of gravitational interaction (see 7.4);

$\left|P^{\mathrm{Sound}}_P\right| = 10^{22} N \cdot m^{-2}$ is partial "sound" pressure of amer gas of P-waves (see 7.3).

12.3. The mechanism of code effect is that P-waves turn gravitational dipoles of polars in a direction of their propagation.

Polars, being already polarized by MBR and polars thermal motion, will line up in chains "in a tail" to each other.

The forces of interattraction of that way oriented polars are much greater then forces of their attraction in the state of free thermal motion.

Polars thermal motion restricts the maximum possible force of polars attraction.

Besides, the attractive force of a body is diminished at the expense of small coupling of polars of a gravitating body with its atoms and with "immovable" relatively to attracting body ether.

13. Macroscopic mechanism of mutual gravitation of bodies

13.1. The bodies mutually irradiate each other by P-waves. An intensity of partial "sound" amer pressure on polars of body 2 is (see (11.4))

$$\tilde{P}^{\mathrm{Sound}}_{12(P)} \cong \frac{\tilde{P}^{\mathrm{Sound}}_P S_P n_P K^{B1}_{Th} M_1}{4\pi R^2_{12}}.$$

13.2. As it was marked above (s.3, s.12), P-waves effect on ether and on bodies has code character: partial "sound" amer gas pressure causes opposite by direction and greater on quantity gravitational attraction.

The force of gravitational attraction (the force of the ether attraction of body 2, caused by P-waves radiation by body 1), can be estimated by quantity

$$\tilde{F}^{\mathrm{Gr}}_{21} = \tilde{P}^{\mathrm{Sound}}_{12_{(P)}} K^P_{\mathrm{Cod}} S_P n_P K_{\mathrm{Coupl}} M_2 = G\frac{M_1 M_2}{R^2_{12}}, \quad (13.1)$$

$$G = \frac{\tilde{P}^{\mathrm{Sound}}_P (S_P n_P)^2 K^B_{Tr} K^P_{\mathrm{Cod}} K_{\mathrm{Coupl}}}{4\pi},$$

coefficient K_{Coupl} takes account of severity of the coupling of P-wave pressure on polars with gravitation force.

13.3. Resultant force of an attraction of body 2 to body 1

$$\tilde{F}^{\mathrm{Gr}}_{12(\mathrm{Res})} = \tilde{F}^{\mathrm{Gr}}_{12_{(P)}} - \tilde{P}^{\mathrm{Sound}}_{12} K_{\mathrm{Coupl}} M_2 =$$

$$= \left(1 - 1/K^{12}_{\mathrm{Cod}}\right) \tilde{F}^{\mathrm{Gr}}_{12} \cong F^{\mathrm{Gr}}_{12}.$$

Accordingly,

$$\tilde{F}^{\mathrm{Gr}}_{21} = \tilde{F}^{\mathrm{Gr}}_{12} = \tilde{F}^{\mathrm{Gr}} = G\frac{M_1 M_2}{R^2_{12}}. \quad (13.2)$$

13.4. All quantities, that are included in expression (13.1), except of coefficient K_{Coupl} were also evaluated quantitatively. Such the estimation can be made for K_{Coupl} too.

On known quantity $G \sim 7 \cdot 10^{-11} m^3/\left(\mathrm{kg} \cdot \mathrm{s}^2\right)$ at $K^{B1}_m = 0.1 K^{B2}_m$ for system Sun-Earth

$$K^{SE}_{\mathrm{Coupl}} \cong 10^{-32}\ \mathrm{kg} \cdot \mathrm{m}^2. \quad (13.3)$$

13.5. Code coefficient of Sun-Earth system

$$K^{SE}_{\mathrm{Cod}} = K^{12}_{\mathrm{Cod}} = K^P_{\mathrm{Cod}} = 10^{16}. \quad (13.4)$$

14. Discussion of the obtained results and conclusions

14.1. Gravitation is one of manifestations of the reciprocal interaction through ether. The mechanism of gravitation consists of a constant reciprocal radiation

of bodies by polarization waves, which excite the forces of ether attraction of irradiated bodies in the direction of their interaction. The mechanism of excitation has code character: the exited attractive forces on a direction are opposite to stimulating ones, and on quantity are much greater than forces, stimulating them. Gravitation energy is transformed energy of ether.

14.2. The most surprising result of the carried out examinations, by the opinion of the author, is the deduction that immediate power action between gravitating bodies does not exist. The existing gravitational interaction has the informational - code character: the gravitating bodies irradiate each other with P-waves, calling an attraction of an irradiated body by environmental ether in a direction of an irradiating body. Thus the energy of the irradiation of a body is on many orders less than energy of its attraction.

14.3. The most important on principle result of the investigation is the discovering of the nature and mechanism of mutual gravitation and through them - the installation of the fact, that all power fundamental interactions (strong, electromagnetic, slight and gravitational) have the uniform mechanical nature.

With reference to strong, electromagnetic and gravitational interactions this deduction follows directly from the obtained results, as applied to slight ones - the additional explanation of its mechanism is required, as so it is - manifestation of the same mechanical forces, but between more complex material structures.

"The Great integration of fundamental interactions", thus, has taken place on the basis of mechanical power interactions.

14.4. The basis of bodies motion dynamic get the further development (Newton's laws). Taking into consideration the ether influence on a body's motion gives that the known laws of motion of bodies will become approximate.

14.5. In some degree the supporters of mystic "torsion" waves get the satisfaction (though they were not able to explain, what is implied in notion "torsion waves"), because drawing interaction between polars in P-waves have "torsion" character.

14.6. The reasons of so long delay (300 years) in the discovering of the nature and mechanism of mutual gravitation of bodies become clear: before the discovery of vacuum polarization waves (1996 [1-4]) they of principle could not be disclosed

14.7. The obtained quantitative estimations of the mechanism of gravitational interactions are very approximate. They were not the purpose of examinations and play only auxiliary role of illustrations of method of approach reasonableness at a justification of principle conclusions (this role they have carried out). As far as practical use of the obtained results is approached, the quantitative estimations, naturally, will be improved.

14.8. There is the principle opportunity to create devices for gravitational and antigravitational forces generation and these forces guidance (gravitational engines, anti-asteroids protection of the Earth, anti-missile protection).

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A COASTING UNIVERSE WITH VACUUM ENERGY

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We have studied a cosmological model with a cosmological term of the form $\Lambda = 3\alpha\frac{\dot{R}^2}{R^2} + \beta\frac{\ddot{R}}{R} + \frac{3\gamma}{R^2}$, α, β, γ are constants. The scale factor (R) is found to vary linearly with time for both radiation and matter dominated epochs. The cosmological constant is found to decrease as t^{-2} and the rate of particle creation is smaller than the Steady State value. The model gives $\Omega^{\Lambda} = \frac{1}{3}$ and $\Omega^{m} = \frac{2}{3}$ in the present era, $\Omega^{\Lambda} = \Omega^{m} = \frac{1}{2}$ in the radiation era. The present age of the Universe (t_p) is found to be $t_p = H_p^{-1}$, where H_p is the Hubble constant. The model is free from the main problems of the Standard Model. Since the scale factor $R \propto t$ during the entire evolution of the Universe the ratio of the cosmological constant at the Planck and present time is $\frac{\Lambda_{Pl}}{\Lambda_p} = 10^{120}$. This decay law justifies why, today, the cosmological constant is exceedingly small.

1. The model

In a Robertson Walker metric, the Einstein's field equations with variable cosmological and gravitational 'constants' and a perfect fluid yield [2]

$$3\frac{\dot{R}^2}{R^2} + \frac{3k}{R^2} = 8\pi G\rho + \Lambda, \tag{1}$$

$$2\frac{\ddot{R}}{R} + \frac{\dot{R}^2}{R^2} + \frac{k}{R^2} = -8\pi G p + \Lambda, \tag{2}$$

where ρ is the fluid energy density and p its pressure.

The equation of the state is usually given by

$$p = \omega\rho, \tag{3}$$

where ω is a constant. Elimination of $\ddot{R}$ gives

$$3(p+\rho)\dot{R} = -\left(\frac{\dot{G}}{G}\rho + \dot{\rho} + \frac{\dot{\Lambda}}{8\pi G}\right)R. \tag{4}$$

2. Particle creation

2.1. Matter-Dominated Universe

For a pressure-less ($p = 0$) Universe, eq.(4) reads

$$\frac{d(\rho R^3)}{dt} = -\frac{R^3}{8\pi G}\frac{d\Lambda}{dt}. \tag{5}$$

In this paper we discuss flat cosmological models with a Λ term varying as [3]

$$\Lambda = 3\alpha\frac{\dot{R}^2}{R^2} + \beta\frac{\ddot{R}}{R} + \frac{3\gamma}{R^2}, \tag{6}$$

where α, β and γ are arbitrary constants.

This model extends the Carvalho *et al.* model to include the possibility of variable gravitational constant [4].

Eqs.(2) and (6) yield

$$(2-\beta)\ddot{R}R + (1-3\alpha)\dot{R}^2 - \frac{3\gamma}{R^2} = 0, \tag{7}$$

which yields

$$\dot{R}^2 = \frac{3\gamma}{(1-3\alpha)} + AR^{-2(1-3\alpha)/(2-\beta)}, \tag{8}$$

where $A =$ constant.

If A=0 (singular solution), one obtains,

$$R = \sqrt{\frac{3\gamma}{(1-3\alpha)}}\, t, \ \alpha < \frac{1}{3}. \tag{9}$$

Eqs.(1), (6) and (9) yield

$$H_p = \frac{1}{t_p}, \ \Lambda(t) = \frac{1}{t_p^2}, \ \rho = \frac{1}{4\pi G}\frac{1}{t_p^2}. \tag{10}$$

where $H = \frac{\dot{R}}{R}$ is the Hubble constant. Hereafter the subscript 'p' denotes the present value of the quantity.

The vacuum energy density (ρ_v) is given by

$$\rho_v(t) = \frac{\Lambda}{8\pi G} = \frac{1}{8\pi G}\frac{1}{t^2}. \tag{11}$$

The deceleration parameter (q) is defined as

$$q \equiv -\frac{\ddot{R}R}{\dot{R}^2} = 0. \tag{12}$$

The density parameter of the Universe (Ω^m) is given by

$$\Omega^m = \frac{\rho}{\rho_c} = \frac{2}{3}, \tag{13}$$

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where $\rho_c = \frac{3H^2}{8\pi G}$.

The density parameter due to vacuum contribution is defined as $\Omega^\Lambda = \frac{\Lambda}{3H^2}$.

Using eq.(10) this yields

$$\Omega^\Lambda = \frac{1}{3}. \tag{14}$$

It is interesting that the above cosmological parameters are independent of the value of α, β or γ.

We shall define Ω_{total} as

$$\Omega_{total} = \Omega^m + \Omega^\Lambda. \tag{15}$$

Hence eqs.(13), (14) and (15) give $\Omega_{total} = 1$. The inflationary paradigm requires this solution. A very recent age of the Universe is shown to be 12 billion years. This would imply that the Hubble constant $H_p = 81\ kms^{-1}Mpc^{-1}$. This value is consistent with the recent Hubble Space Telescope determination of $h = 0.80 \pm 0.17$ [5].

We now turn to calculate the rate of particle creation (annihilation) n, which is defined as [6]

$$n = \frac{1}{R_p^3}\frac{d(\rho R^3)}{dt}|_p. \tag{16}$$

Using eqs.(5), (9) and (10), eq.(16) yields

$$n_p = \rho_p H_p. \tag{17}$$

We remark that this rate is less than that of the Steady State model $(= 3\rho_p H_p)$.

3. A model with variable G

We now consider a model in which both G and Λ vary with time in such a way the usual energy conservation law holds.

Equation (4) can be split to give [2]

$$\dot{\rho} + 3H\rho = 0, \tag{18}$$

and

$$\dot{\Lambda} + 8\pi\dot{G}\rho = 0. \tag{19}$$

3.1. Matter-Dominated Universe

Using eqs.(9) and (10), eqs.(18) and (19) yield

$$\rho(t) = A't^{-3}, \tag{20}$$

and

$$G(t) = \frac{1}{4\pi G A'}\ t,\ A' = \text{const.} \tag{21}$$

This solution is obtained by Berman and Som [7] and can be obtained from Berman's model [8] with $[m = 1, \alpha = 0]$.

It has been shown that the development of the large-scale anisotropy is given by the ratio of the shear σ to the volume expansion $(\theta = 3\frac{\dot{R}}{R})$ which evolves as [9]

$$\frac{\sigma}{\theta} \propto t^{-2}. \tag{22}$$

The present observed isotropy of the Universe requires this anisotropy to be decreasing as the Universe expands. Thus an increasing G guarantees an isotropized Universe.

3.2. Radiation-Dominated Universe

This is defined by the equation of the state $p = \frac{1}{3}\rho\ (\omega = \frac{1}{3})$. Eqs.(1), (2) and (6) yield

$$(1-2\alpha)\frac{\dot{R}^2}{R^2} + (1-\frac{2}{3}\beta)\frac{\ddot{R}}{R} - \frac{2\gamma}{R^2} = 0, \tag{23}$$

which gives

$$\dot{R}^2 = \frac{2\gamma}{(1-2\alpha)} + BR^{-2(1-2\alpha)/(1-\frac{2}{3}\beta)}, \tag{24}$$

where B=const. For B =0 (singular solution), one obtains

$$R = \sqrt{\frac{2\gamma}{(1-2\alpha)}}\ t,\ \alpha < \frac{1}{2}. \tag{25}$$

Eqs.(1) and (6) give

$$\Lambda = \frac{3}{2}\frac{1}{t^2},\ \rho = \frac{3}{16\pi G}\frac{1}{t^2}. \tag{26}$$

It has been pointed out that we need not have an inflationary phase (exponential law for R) because there is no horizon problem with the above solution [8]. We see from eqs.(10) and (26) that the ration of the cosmological constant at the Planck's time ($t_{Pl} = 10^{-43}$ sec) and the present time ($t_p = 10^{17}$ sec) is $\frac{\Lambda_{Pl}}{\Lambda_p} = (\frac{10^{17}}{10^{-43}})^2 = 10^{120}$. Thus Λ, today, is exceedingly small because the Universe is too old!.

Eqs.(15) and (26) yield

$$\Omega^r = \Omega^\Lambda = \frac{1}{2}. \tag{27}$$

Again we see that the above cosmological parameters are independent of the value of α, β or γ. Equation (27) shows that the radiation and vacuum contributes equally to the total energy density.

4. A model with variable G

Equation (4) now reads

$$\dot{\rho} + 4H\rho = 0, \tag{28}$$

and

$$\dot{\Lambda} + 8\pi\dot{G}\rho = 0. \tag{29}$$

Employing eqs.(1) and (6), eqs.(28) and (29) yield

$$\rho = \mathrm{B}'\mathrm{t}^{-4}, \quad \mathrm{G} = \frac{3}{16\pi \mathrm{B}'}\mathrm{t}^2, \quad \mathrm{B}' = \mathrm{const.} \tag{30}$$

Recently, Abdel Rahman [2] and Berman [7,8,10] (with $[m = 1, \alpha = \frac{1}{3}]$) have found that $\mathrm{R} \propto \mathrm{t}, \mathrm{G} \propto \mathrm{t}^2, \rho \propto \mathrm{t}^{-4}$ in the radiation era.

5. Conclusion

We have analyzed in this paper the effect of the assumed decay law for the cosmological constant. The only possible solution is the $R \propto t$ for the radiation and matter dominated epochs.

Berman obtains this solution (for Brans-Dicke models with a time dependent cosmological term) for the matter and the radiation epochs and by Abdel Rahman for the radiation epoch. There is no horizon or age problem associated with this solution. Our model predicts that $\mathrm{H_p} = 81\ \mathrm{kms^{-1}Mpc^{-1}}$ if the age of the Universe is 12 billion years.

Thus by introducing the cosmological constant it is possible for a flat model to be in accordance with the Universe age even with high values of $\mathrm{H_p}$. We stress that the decay law $\Lambda \propto t^{-2}$ indeed plays an important role in cosmology as remarked by Berman. A natural extension of this work would be to investigate different scenarios by considering non-singular solutions, i.e., solutions with A and B negative.

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THE IDENTITY OF GRAVITATIONAL MASS/INERTIAL MASS. A SOURCE OF MISUNDERSTANDINGS

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With the aim of removing some frequent misunderstandings, I attempt to clarify the differences between inertial and gravitational mass.

1. Introduction

Newton never pre-judged the proportionality between inertial mass and gravitational mass. On the contrary, he performed his famous experiments with the aid of pendulum filled with different substances, in order to check the above proportionality, suggested by Galilei when dealing with free-fall.

With the above experiments Newton secured the ratio

$$\frac{\text{gravitational mass}}{\text{inertial mass}} = \frac{m_g}{m_i} = C \tag{1}$$

within some 10^{-3} relative uncertainty. We named [1, 2] the *Second law of Newton's gravitational theory* the statement given by equ. (1).

The *First law of Newtonian gravitational theory* reads:

$$F^N = \frac{m_{g1} m_{g2}}{r^2}. \tag{2}$$

In which m_{gj} means the *gravitational mass* of the point particles *1, 2*, respectively.

We consider the gravitational mass as being a *primary* magnitude [3], similar in this sense to the electric charge and to the spin. A primary magnitude cannot be derived, *up to now*, from other previously known properties.

Some authors prefer to write equ. (2) with a multiplicative constant η, $F^N = \eta\,(m_{g1} m_{g2})\,/r^2$. We will show that the above constant is *superfluous*.

First at all, gravitational force doesn?t depend upon the medium in which the particles are immersed. There is no *gravitational permittivity*. This is a very important difference when comparing with the Priestley-Coulomb law. η being a number *independent of the medium*, for the *sake of symmetry*, it will affect in the same way each point mass. Thereby, $F^N = \left[\left(\sqrt{\eta} m_{g1}\right)\left(\sqrt{\eta} m_{g2}\right)\right]/r^2$. In such a case, we *define* $m'_{gj} = \sqrt{\eta} m_{gj}$ as being the gravitational mass of the point mass j. QED. **"We must avoid including superfluous elements in the description of physical phenomena." Is. Newton, Principia**.

By inserting equ. (1) in equ. (2) we get the familiar force law, written in terms of *inertial masses*, m_{ij}.

$$F^N = C^2 \frac{m_{g1} m_{g2}}{r^2} = G \frac{m_{g1} m_{g2}}{r^2} \tag{3}$$

wherein $G = C^2 = 6.67 \times 10^{-8}\ cm^3 g^{-1} s^{-2} = 6.67 \times 10^{-11}\ m^3 kg^{-1} s^{-2}$.

With the above analysis we rewrite equ. (1) as:

$$m_{gj} = \sqrt{G} m_{ij}. \tag{4}$$

Equation (4) allows us to grasp the "size" of the standard of gravitational mass in terms of the most familiar standards of inertial mass. Thus, in the CGS system, a body having 1 *Unit* of gravitational mass has an inertial mass amounting to $1/\sqrt{G} \approx 4 \times 10^3\ g$, i.e. some 4 kg. From equ. (2) and $[F] = L^1 M^1 T^{-2}$ we deduce the *dimensional formula* for gravitational mass,

$$[m_g] = L^{3/2} M^{1/2} T^{-1}, \tag{5}$$

wherein the Maxwell's bracket means the ratio of the standards employed to measure gravitational mass in two *coherent* systems of units (such as the CGS and the MKS), $[m_g] = U'_{mg}/U_{mg} = a\ real\ namber$. The same meaning have the symbols $L = U'_L/U_L$ for lenght, and M and T, for inertial mass and time, respectively [4].

On account of equ. (5) we get $U'_{mg} = U_{mg}\,(100/1)^{3/2}\,(1000/1)^{1/2}\,(1)^{-1} = 3.162 \times 10^4$, being U'_{mg} and U_{mg} the MKS and CGS standard of gravitational mass, respectively.

Due to historical arguments [4-6] we propose the name *schrodinger* (*Sch*) for the CGS standard, U_{mg}, and the name *palacios* (*Pal*) for the MKS standard.

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Thus, $1\,Pal = 31.620\,Sch$, despite the fact that $1\,kg = 1,000\,g$.

Einstein [7] based his GTR upon the relation $m_g = m_i$, which, according to our above analysis, is physically untenable He said *"we achieve the equality of the two masses by choosing a suitable set of standards."* But, in practice, Einstein forgot to describe his suitable set of standards.

2. Post-Newtonian formulations

Recently A.K.T.Assis was able to enhance Newtonian physics explaining at once the origin of inertia [8-10] according to Mach?s ideas. His starting point was a Weber-like force, which reads, in obvious notation,

$$F^{WA} = F^N \left(1 - \frac{\xi \dot{r}^2}{2c^2} + \frac{\xi r \ddot{r}}{c^2}\right). \tag{6}$$

The otherwise excellent work of Assis is ambiguous concerning the neat distinction between inertial and gravitational masses. We have improved it in accordance with our above considerations [1-3, 11].

With the aid of equ. (6) Assis calculates the force, F_{Uk}, exerted by the whole isotropic universe on an accelerated test particle having gravitational mass m_{gk}: $F_{Uk} = -m_{gk}\Phi_A a$, wherein $\Phi_A \equiv \left(2\pi\xi G\rho_{g0}/3H_0^2\right)$. In order to recover Newton?s second law Assis is constrained to take $\Phi = 1$, with which inertial mass becomes identical to gravitational mass. In our version of Relational Mechanics [1, 2, 11] we take $\Phi_{GV} \equiv \left(2\pi\xi G\rho_{g0}/3H_0^2\right)$, with which inertial mass, m_{ik}, becomes $m_{ik} \equiv m_{gk}\Phi_{GV}$, and, on account of equ. (4) we get $G \equiv \left(3H_0^2/2\pi\xi G\rho_{g0}\right)^2$. Since the density of inertial mass, ρ_{i0}, also scales as inertial mass, it will be [1, 2, 11]

$$\rho_{i0} = \rho_{g0}\Phi_{GV} \propto \left(\rho_{g0}\right)^2. \tag{7}$$

Equation (7) has a clear physical meaning: an increase in the density of inertial mass arises from to two different causes:

1) An increase in the number of galaxies also increases ρ_g ("cumulative effect") and, consequently ρ_l. Thus $\rho_l' \propto \rho_g$, a fact covered by Assis?s formulation.

2) The increase in the density of gravitational mass also increases the individual inertial mass of each particle [1, 2] (here is the core of Mach?s Principle!). Therefore, it will be $\rho_l'' \propto \rho_l' \quad \rho_g \propto \rho_g^2$, in accordance with equ. (7).

Since $\Phi_A = 1$ in Assis's algorism, the two above described facts are not manifest.

On account of equ. (7) we find $G \equiv 3H_0^2/2\pi\xi G\rho_{g0}$ in agreement with the relation advanced by Dirac [14].

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COSMIC MASER AS A REMOTE QUANTUM DETECTOR OF THE GRAVITATIONAL WAVES: ON THE POSSIBILITIES OF THE OMPR-BASED METHOD

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A new method based on the phenomenon of the optical-mechanical parametric resonance is proposed to detect the gravitational waves. The atoms and molecules responsible for the radiation of the cosmic masers can be described in frames of the two-level system model. The distance between these atoms and the Earth oscillates when the gravitational wave falls upon them. This affects the observable maser spectrum and a low frequency nonstationary component appears on it. The frequency of this component corresponds to the frequency of the gravitational wave. The needed astronomical observations and the additional instrumentation are described.

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1. Introduction

This paper presents not a new result but rather a new idea based on the recently theoretically discovered effect of the optical-mechanical parametric resonance (OMPR) [1], [2] . The essence of it is that under special conditions the mechanical motion of atoms driven by a strong electromagnetic (EM) field essentially affects the observable spectrum. In case the atoms take part in the periodical motion (oscillate), a nonstationary component with large amplitude appears on the spectrum. Such a situation might take place when a gravitational wave (GW) produced by a periodical source passes through a cosmic maser whose signal is observed from the Earth. In spite of the fact that there is a number of serious questions that still remains, the discussion of the idea to regard a cosmic maser as a part of an instrument – remote quantum detector – to observe the GW with the help of specially modified radiotelescope might be of interest to the researchers.

Cosmic masers are the interstellar clouds where the concentrations of atoms are higher than the average. The atoms in these clouds may be excited by various external sources and emit the microwave radiation. Due to stimulated transitions (maser effect) the radiation is highly monochromatic, and its intensity grows as the radiation passes through the cloud. These regions are well observed from the Earth, their typical brightness temperatures being $10^8 \div 10^{12} K$, which corresponds to the flux density of $10^2 \div 10^4 Jy$. The theory and experimental data for these objects are discussed in [3], [4].

Briefly speaking, the OMPR constitutes the following. Take a gas consisting of the two-level atoms (TLA), and let the strong resonant EM radiation pass through this gas. Use some periodical external source to bring the atoms into simultaneous mechanical oscillations (in laboratory frame) in parallel to the radiation beam. Let us assume that a) there is a non-zero detuning of the EM radiation frequency Ω from the frequency of the atomic transition ω, b) the amplitude of the atomic mechanical oscillations suffices the amplitude condition

$$\frac{kV}{\alpha} \sim \varepsilon \tag{1}$$

here k is the wave vector of the electromagnetic field, V is the atomic velocity due to oscillations, $\alpha = \frac{Ed}{2\hbar}$ is Rabi parameter (or Rabi frequency), E is the electric component of the field, d is the dipole moment of the atom, $\hbar$ is Planck's constant, ε is a small dimensionless parameter), and c) the frequency of the mechanical oscillations, D, suffices the tuning (or parametric resonance) condition

$$D = 2\sqrt{(\Omega - \omega - \frac{kV_0}{2})^2 + \alpha^2} \tag{2}$$

(here V_0 is the thermal velocity of an atom). These conditions sufficed, the observable spectrum (absorption or radiation) essentially deforms and obtains a

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characteristic nonstationary feature, the amplitude of which is much larger than the height of the stationary resonant peak. 'Nonstationary' means that the absorption coefficient will have an additional component, the amplitude of which is a cosine function of time. This amplitude obtains both positive and negative values. Negative values in absorption correspond to the amplification, and, therefore, the mean (averaged over time) signal will be absent, because the amplification during one half of a period compensates the absorption during the other half of a period. But if the observation is performed with the help of an additional device like a lock-in amplifier, it is possible to register a signal at the frequency equal to the frequency of oscillations (and, as it was shown, it will be essentially higher than the regular stationary signal at the resonance frequency).

The curvature waves produced by a GW source act both on the Earth and on cosmic maser and lead to the varying of the separation between the Earth and maser's atoms, i.e. the distance between the atoms and the Earth oscillates. This is similar to what can take place in the laboratory investigations of the OMPR, when the distance between the (vibrating) atoms and the detector oscillates. Provided the OMPR conditions are fulfilled and the observation of maser radiation is modified in an appropriate way, the effect of the GW action could be registered, thus, giving the direct evidence of the GW existence. The sensitivity of the instruments now in use is sufficient to perform the measurements in question, since the stationary maser signals are easily detected by the existing radiotelescopes and the expected signal is larger than the signals already observed.

Unfortunately, this does not mean that the problem of the GW detection could be, thus, easily solved. Though technical problems of the instrument's sensitivity and noise filtration practically vanish, a purely astronomical and in a sense astrophysical problem of the search of the suitable maser arises. Nevertheless, it seems that the discussion of the applicability of the new principle to the solution of one of the most challenging problems of modern physics could be useful.

2. Detection of the gravitational waves

To apply the ideas supporting the OMPR effect to the GW detection with the help of the cosmic masers one has to check up three groups of assumptions:

(i) the physical backup: a) there must be a gas of the TLAs and a resonant monochromatic field that is strong in the spectroscopical sense, i.e. its Rabi parameter, α, is larger than the TLA's excited state decay rate, γ; b) there must be a source that provides the oscillatory motion of the TLAs;

(ii) the OMPR conditions: a) Rabi frequency must be of the same order as the frequency of the atoms oscillations; b) the amplitude of the oscillations must provide the possibility of the effect;

(iii) the observation possibilities: a) the relative location of the GW source, the maser and the observer; b) the instrument's sensitivity.

2.1. Physical backup

There is a number of various masers [5], [6] in space functioning in some of the regions where the concentrations of H, OH, H_2O, SiO and other atoms and molecules are higher than the average. The spectrum peaks corresponding to the radiation from these objects have the radio frequency and the line widths of such masers are usually about $(2 \div 10) * 10^3 s^{-1}$. All these atoms and molecules in our case can be described in frames of the two-level system model (and will be called TLAs). If there is a pumping mechanism, the medium with the inverse population occurs. Two types of space masers are known: unsaturated and saturated, the latter being the one where the field is strong in the spectroscopical sense. The important thing is that in the saturated maser the intensity of radiation grows linearly [5] while propagating through the maser. The star shells also present suitable regions for space masers that could be of interest in view of our goal.

A rotating astrophysical object with the nonzero quadrupole moment can be a source of the tensor GW and a radially pulsating object – a source of scalar GW. In this paper we will concentrate upon the periodical sources such as rotating neutron stars (e.g. the pulsar PSR 0532 in Crab nebulae). In this case the GW-source is highly monochromatic [7]. A GW produced by a source causes the varying of the distance between any two points with the frequency, D, equal to that of the GW. When the mechanical oscillations of atoms take place in a laboratory set up, the distance between the atoms and the detector (that presents the laboratory reference frame), also changes in the similar manner. It is this effect that can lead to the OMPR in the laboratory, and this is why it is possible to apply the OMPR for the search of the GW with the help of cosmic masers.

The intensity of the driving EM field interacting with the atom is characterized by Rabi parameter (or Rabi frequency) $\alpha = \frac{Ed}{2\hbar}$. The "strong" field means that the stimulated absorption-emission governs the atomic behavior, i.e. $\gamma/\alpha \sim \varepsilon$ where ε is small. In view of our goal and with regard to the OMPR conditions discussed further, α must be of the same order as D – the frequency of the mechanical oscillations. The GW frequencies vary from $10^1 s^{-1}$ for the periodical sources (e.g. pulsar in the Crab nebulae) to $10^3 s^{-1}$ corresponding to the catastrophic events in the Galaxy nucleus [9], [14]. Let a periodical source have frequency proportional to $10^1 s^{-1}$. Then, if we assume $\varepsilon \sim 10^{-2}$, the value of the excited state decay rate γ corresponding to the strong field should be of the order of $10^{-1} s^{-1}$, i.e. the excited state of

the atom is metastable. In [15] it was found that the OH-radical has a suitable rotational transition (its frequency [16] is of the order of $10^9 - 10^{10}\,\mathrm{s}^{-1}$) with $\gamma = 10^{-1}\mathrm{s}^{-1}$. In [15] this value was used to evaluate the OH space maser dimensions. The intensity of the radio signal coming to the Earth from a typical OH-maser corresponds to the intensity I at the maser border equal to $I \sim 10^{22}\,\mathrm{W}$, while a typical maser dimension has a value of $r_m \sim 10^{12}\,\mathrm{m}$. To evaluate the electric stress of the field at the maser border E_m, the formulas for the power flow $S = \frac{I}{4\pi r_m^2}$ and $S = \varepsilon_0 c E_m^2$ ($\varepsilon_0 = 8.85 * 10^{-12}\,\mathrm{F\cdot m^{-1}}$ – absolute dielectric permittivity) can be used, and the stress appears to be $E_m \sim 10^0\,\mathrm{V\cdot m^{-1}}$. Substituting this value into the formula for Rabi frequency, we see that in the depth of the maser cloud there *is* a region with $\alpha \sim 10^1\,\mathrm{s}^{-1}$ providing the chosen value $\varepsilon \sim 10^{-2}$. And the OH maser sources are frequent in space.

Thus, there are regions in space where there exist the two-level atoms driven by a strong resonant monochromatic field (e.g. OH-masers), and there exist the external sources (e.g. pulsars) that can "make these atoms oscillate" with regard to the Earth location when the GW passes through the maser.

2.2. OMPR conditions

The OMPR conditions a), b) (eq.1) and c) (eq. 2) mentioned in the Introduction were obtained in [1], [2] .

A non-zero detuning of the radiation frequency from the frequency of the atomic transition can be delivered by the consideration of the non-zero velocity of the interstellar gas leading to the Doppler shift of the resonance frequency.

Let us now evaluate the needed amplitude of the atoms' oscillations providing the OMPR. Substituting $D \sim 10^1\mathrm{s}^{-1}$, $\gamma \sim 10^{-1}\mathrm{s}^{-1}$, and $\omega \sim 10^{10}\mathrm{s}^{-1}$ into eq.1, we find that the vibrating maser's atom must have the amplitude of vibration equal to $A \sim 10^{-4}\mathrm{m}$. This value of the amplitude can cause the effect in the case under discussion. The possibility to have this value for maser observations is discussed in the next subsection.

To suffice the resonance condition, the GW frequency must be proportional to the maser radiation intensity, and $D \sim \alpha$. But the maser diameter is very large, and the radiation intensity varies while propagating through the maser. Thus, the precise tuning for the given frequency of external action – that is the expected GW frequency – can be reached only in the region of a maser where Rabi frequency suffices the OMPR condition. For other maser's parts located further and nearer to the observer, this condition would be broken. But the existence of an OMPR-region, even though it is just a part of a maser as a whole, could be enough to provide the main thing – that is the appearance of the nonstationary component in the spectrum. Observed with the help of an additional device like a low frequency lock-in (LFL), it would point at the OMPR caused by the atoms' oscillation. Other effects like weak field resonance fluorescence, or Doppler driven spectral changes would not count in the *nonstationary* component of the signal. There is a possibility that the amplitude of the observable nonstationary signal would not be higher than the value of the stationary signal already observable. This can happen in the case when the maser OMPR-region is far from the closest to the Earth maser "border" . Still the hope remains to recognize the existence of the OMPR caused by the gravitational radiation with the help of an LFL and observe only the low frequency GW- modulated part of the maser signal.

Let us now evaluate the longitudinal and transversal dimensions of the OMPR-region with regard to the observation line (OL). Considering the spatial extent of the cosmic maser, the attention should be paid to the following: a) could the EM radiation propagating through the maser and along the OL consequently meet atoms with counterphase displacements with regard to the Earth, that will, thus, destroy the effect?; b) could the EM radiation from the points that are situated at half a GW wavelength from one another along the GW wave vector (i.e. perpendicular to the OL) be self compensating when being registered by an instrument on the Earth? Question b) deals with the angular resolution of existing instruments. The point of observation must have the angular dimension that is less than half of the GW wave length, which is equal to $\frac{c}{D}$ and in our case is about $10^6 \div 10^7\,\mathrm{m}$. This is within the resolution possibilities of the modern radiotelescopes. Question a) is more complicated and demands the following analysis. One has to estimate the longitudinal dimension of the region where the OMPR conditions are fulfilled, and make sure that it is not larger than the half of the GW length. Since E^2 grows linearly while the EM radiation propagates through the maser, we can estimate the distance passed by the radiation until the OMPR tuning condition is broken. Let E_m^2 correspond to the maser border (i.e. to the observable stationary signal), r_m is maser dimension, E_R^2 is the field needed to provide the value of Rabi frequency sufficing the tuning condition, r is the distance between the maser's border (furthermost from the observer) and the region where the OMPR could take place. When the radiation reaches $r + \Delta r$ point, the intensity becomes proportional to $(E_R + \Delta E)^2$. The linear increase of the intensity in the saturated masers leads to the simple proportions $\frac{r+\Delta r}{r} = \frac{(E_R+\Delta E)^2}{E_R^2}$ and $\frac{r}{E_R^2} = \frac{r_m}{E_m^2}$, which give $\Delta r = 2\frac{E_R \Delta E}{E_m^2} r_m$. The electric component E_R is proportional to Rabi frequency α , and if the parametric resonance tuning $\Delta\alpha$ is chosen to be equal to $\varepsilon\alpha$, then ΔE will be equal to εE_R. Thus, for the longitudinal

dimension of the OMPR region one gets

$$\Delta r = 2\varepsilon \frac{E_R^2}{E_m^2} r_m \tag{3}$$

For the typical OH-masers the squared electric stress at the border is $E_m^2 \sim 10^0\,\mathrm{V}^2\cdot\mathrm{m}^{-2}$. In the definition $\alpha = \frac{E_R d}{2\hbar}$ one should choose $\alpha \sim 10^1 s^{-1}$, the dipole moment is [17] $d = 6\cdot 10^{-30}\,\mathrm{C}\cdot\mathrm{m}$, then in the OMPR region of the maser $E_R^2 = \frac{2\hbar\alpha}{d} \sim 10^{-3}\,\mathrm{V}^2\cdot\mathrm{m}^{-2}$. Substituting these values into eq.3 , one gets $\Delta r \sim 10^5\,\mathrm{m}$. If the maser intensity is larger than the mentioned typical value, then the OMPR region is more compact, and the possibility to suffice the tuning condition increases. Note, that simultaneously the number of atoms taking part in the effect decreases, and higher density of the cloud is needed. If the maser intensity is less than the given value, the OMPR region increases, and the atoms separated by the distance larger than the GW length move in the counterphase and can destroy the effect. Thus, the OMPR conditions can be fulfilled, but a suitable maser must be carefully selected.

2.3. Observation possibilities

Now let's investigate the possibilities for the maser location to meet the needed value of the amplitude. The metric tensor component $h = \mid h_{\alpha\beta} \mid$ corresponding to the gravity radiation emitted by an object like a neutron star is inversely proportional to the distance from the source, and is equal [7], [8] to

$$\mid h_{\alpha\beta} \mid \simeq \frac{GML^2D^2}{c^4 r} g_e \tag{4}$$

where G is the gravitation constant; M is the star mass; L is the star linear dimension; r is the distance to the region where the GW acts on a detector (here: on a TLA in a maser), g_e is the gravitational ellipticity in the equatorial plane of a star.

The free bodies methods of the GW detection take into account the relation $\frac{l_1}{l} = \frac{1}{2}h$, where l is the distance between the two free bodies at small separation in the flat space (interferometer mirrors), and l_1 is the variation of this distance due to curvature waves [9]. The value of l_1 will reach its maximum for the local detector, when l (the interferometer arm) is equal to the half of the GW length. In all the other cases, be l several times less or larger than this value, the situation won't improve because the value of h for the *local* detector remains the same. But for the *remote* quantum detector the situation is different. One of the two free bodies in question (here: OMPR region of a maser) can be located in a region where h is essentially larger, i.e. in the vicinity of the star (GW source). The most favorable position for the maser is on the circle, the diameter of which connects the Earth and the GW source. In this case the distance between the (tensor) GW source and the Earth does not variate due to this source's gravity radiation, while the maser-to-Earth distance variates in the maximal way. To enlarge the amplitude of the maser's atom oscillations (in the Earth reference frame), the maser should be close to the GW source.

Let us evaluate the distance from the GW source to a place, where the displacement l_1 of the maser's atoms suits the OMPR amplitude condition $A = 10^{-4}$ m obtained in the previous subsection. To do this let us pretend that we deal with the *local detector*, and its interferometer arm is equal to the half of the GW length, i.e. $l \sim 10^6$ m. Then for $l_1 \sim 10^{-4}$ m, the formula $\frac{l_1}{l} = \frac{1}{2}h$ gives $h \sim 10^{-10}$ which is enormous in comparison to its value on the Earth but is reasonable for the star vicinity. Notice, that this value is still small enough to be within the assumptions of the weak field general relativity approach. Substituting this value of h and, e.g., Crab pulsar's characteristics $M = 2.4 * 10^{30}\,\mathrm{kg}$, $L = 1.2 * 10^4\,\mathrm{m}$, $D = 63\,\mathrm{Hz} \sim 400\,\mathrm{s}^{-1}$, into eq.4 and taking [8] $g_e = 6 * 10^{-4}$, we obtain $r \sim 10^5\,\mathrm{m}$. This is just below the border of the wave zone for the Crab GW source. If we consider Vela pulsar that has the similar values for mass and dimension [10] but has $D = 22$ Hz and $g_e = 4 * 10^{-3}$ [8], we get the same order of the distance in question $r \sim 10^5\,\mathrm{m}$. The gravitational ellipticity factor could play an essential role in the estimation of r, but the known values for it vary in different papers (e.g. in the earlier work [11] there were $g_e = 3 * 10^{-6}$ for Crab and $g_e = 3 * 10^{-5}$ for Vela, both of which are worse in view of our goal). This means that the search for the GW source has the additional restriction due to the gravitational ellipticity factor.

Now let us drag one of the mirrors of our interferometer as far as the Earth. In view of the "interferometric" observational possibilities, this will not change the experimental situation significantly. Notice also, that as we saw in the previous subsection, the dimensions of the OMPR maser region is comparable to the GW length. This means that the neighboring maxima and minima of the GW will not compensate each other when driving the atoms.

The chance of an astronomical maser being located within the due distance from a suitable rotating and distorted neutron star is rather low, but as it was already mentioned earlier the star shells can also reveal maser properties. In [12], [13] there are some examples of the atmospheres around neutron stars in X-ray binaries, though the atmospheres discussed there are far different from those that could support an astrophysical maser. Particularly, the soft X-ray thermal radiation field would completely dissociate any of the molecules required for an astrophysical maser. This last problem can be avoided by assuming a single neutron star that has cooled to a very low surface temperature, if that can occur in a Hubble time.

The density of the maser region must be high enough to provide the sufficient number of atoms taking part in the OMPR. Let there be 10 atoms on every linear centimeter of the OMPR maser region along the observation line. Then for $\Delta r \sim 10^5$ m there will be 10^8 atoms, which is a detectable number of atoms even for a regular experiment in which the stationary component is registered.

The conclusion is that the suitable maser must be located in a star vicinity. In this case the corresponding observations in search for the GW with the help of OMPR will be possible. The sensitivity of the existing instruments able to measure the regular maser signal is enough to observe the high nonstationary peak. This means that the signal-to-noise ratio will not be a problem when the suggested method is used.

3. Discussion

The method discussed in this paper differs from the known methods and suggests a direct observation of GW in contrast to that of [18]. It is based on the new principle which is the registration of the OMPR in cosmic masers. As it follows from the reasoning given above, the sensitivity of the already existing astrophysical instruments is enough to detect the effect if any. Thus, the problem in question changes: from a purely technical struggle for the high sensitivity it becomes an astronomical search for a suitable maser.

The following plan of the experiment can be proposed. The radio telescope is fixed at the suitable TLA transition of the selected space maser. The maser signal registered by a radiotelescope is processed by an additional low frequency lock-in amplifier. Simultaneously, the lock-in is synchronized with a reference strobe signal from the low frequency generator working at $10^1 - 10^3$ s^{-1}. The search at the frequencies corresponding to the periodical GW sources is to be performed. In case the conditions of the OMPR are fulfilled the low frequency peak will appear and present a proof of the GW existence. This signal can be distinguished from the others because it reveals itself in the *nonstationary* component of the signal.

In conclusion it should be underlined once again that this paper is devoted to the discussion of the new method of the GW detection. Instead of dealing with the technical difficulties in the Earth laboratories, we confront the problem of the search for the suitable cosmic maser which is not that easy. As it was shown, the needed astrophysical conditions are at the limit of the method's applicability. The discussed approach gives a new direction of thought for the problem of the gravitational waves detection.

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